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NOVEMBER 1946

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SCHOOL SCIENCE
AND
MATHEMATICS

VOL. XLVI NOVEMBER, 1946 WHOLE NO. 406

HOW A CITY PLANS FOR CONSERVATION EDUCATION*

CHARLES H. PHILPOTT, *Principal*
Harris Teachers College, St. Louis, Missouri

The problem of conservation education in St. Louis may be approached from the standpoint of (a) what has been accomplished in the past, (b) what is being done now, and (c) what is hoped for in the future.

Those of us who are concerned with the problems of conservation education in St. Louis at the present time do not claim to be pioneers in any sense. We feel very humble as we view the accomplishments of those who have labored before us. We feel that we are the product of and the lineal descendants of a long line of St. Louis tradition and interest in the field of conservation education. From the very earliest days in St. Louis this spirit has shown itself among our laymen and teachers and scientists. May I review a few of the ways in which this spirit has manifested itself in our city in the past.

In the early days a wealthy business man, Henry Shaw, under the guidance and leadership of those interested in conservation, founded the Missouri Botanical Garden. During the many years of its existence the Missouri Botanical Garden has been promoting the conservation education of the children and adults of the community.

For many years a number of lay organizations in St. Louis have been actively promoting conservation education in some of its phases. The Academy of Science of St. Louis, founded in

* Presented at the 41st Annual Meeting, American Nature Study Society, St. Louis, Missouri, March 29, 1946.

1857, has been a leader in the field. Through its leadership a business man by the name of Wiedman used his means and spare time in producing what we consider here to be a classic in science from the Midwest, Wiedman's *Birds of Missouri*. Similarly an engineer by the name of Hurter produced *The Herpitology of Missouri*, a volume that has stood the test of time.

These publications are mentioned here, not because they are considered to be more important than other scientific accomplishments of the community, but because they are the products of laymen and because they represent the spirit of St. Louis in the field of conservation.

Years ago a very active organization grew up in our city known as the St. Louis Bird Club. It is for the most part an organization of adult laymen and laywomen. Today this organization has a large membership and its lecture program attracts large audiences.

The Nature Study Movement came early to St. Louis where it acquired good leadership and exerted great influence on our educational system. The Nature Study Society for many years has been one of the most active organizations among teachers. Each year it has sponsored field trips and excursions which have been and still are popular with teachers. A list of a few of these excursions illustrates the contribution that the society has made in the conservation education program.

A visit of 75 teachers to Stark's Nursery at Louisiana, Missouri, for the study of nursery problems and methods.

A visit of a group of teachers to the Agricultural Experiment Station at Columbia, Missouri. A high spot on this trip was an examination of an experimental plot where a rotation of lespideza and wheat crops was in progress as a means of building and conserving soil.

A week-end encampment of a group of teachers in the Clark National Forest, in South Missouri for an intensified program of instruction in forestry, under directions of members of the Forestry Service.

Another week-end encampment at Camp Wyman devoted to studies in fire control, wild life, and instruction in soil conservation.

A Saturday week-end excursion and exploration through the American Bottoms (across the river from St. Louis), under the leadership of competent geographers.

A boat trip of a large party down the Mississippi River to St. Genevieve, Missouri, the oldest city in the state. On this trip a study was made of river problems.

A trip to Purina Farm, near St. Louis, where experiments on animal feeding are in progress under the direction of a local commercial firm. This is a small farm on which one fourth million dollars worth of farm products are produced each year.

A visit to Gray's Summit Arboritum of the Missouri Botanical Garden for the study of field ecology.

Several visits to the Federal Fish Hatcheries in Forest Park in St. Louis.

Visits to the swamp region near the junction of the Missouri and the Mississippi Rivers for the study of water birds.

Visits to the Pere Marquette State Park in Illinois for the study of wild life.

The St. Louis Nature Study Society publishes a monthly bulletin which is distributed to teachers in all of the public schools of the city.

In the 1870's William T. Harris, the Superintendent of Schools of St. Louis, pioneered in the development for the city of a comprehensive and balanced course of study in science for the grades. This was to take the place of the object-lesson procedure in science teaching, previously prevailing here, a hit-and-miss method which sampled a little science here and there and allowed the teacher to ride his hobby instead of presenting science as a whole.

This is a glimpse of some of our backgrounds of and for conservation education in St. Louis. It puts the fear of the Lord into those of us who are trying to promote the program in St. Louis today.

Now may I review some of the things that we are trying to do today in St. Louis in the field of conservation education. In this connection I desire to refer briefly to (a) our program of pre-service education for teachers, (b) our program of in-service education of teachers, (c) our program of school supervision, and (d) our efforts in improving the St. Louis Course of Study.

For the pre-service education of teachers St. Louis maintains two teachers colleges, the Harris Teachers College and the Stowe Teachers College. Each college administers a four and one-half year curriculum for the training of teachers for the elementary schools of St. Louis. Since these colleges specifically train teachers for the elementary schools of St. Louis, an opportunity is provided to set up a program of training for conservation education required of all who are to become elementary teachers in the system. We are not sure that the program or conservation education that has been inaugurated for teachers is all that it should be, but we have given much thought to the subject and what we are doing represents the best of our judgment at present.

The two teachers colleges in St. Louis do not offer a required course in conservation education. We prefer, rather, to present

the philosophy and program of conservation as an integrated part of all of our required courses in biological and physical sciences, geography, health, social studies and education. A course in philosophy of education, for instance, which does not properly represent the philosophy of conservation is not a good course in the philosophy of education. We expect our courses in economics and sociology to do justice to the philosophy and principles of conservation. Certainly the factual content of our conservation program should be presented in college biology, chemistry, geography and health education; and the methodology of it should be in our education courses. Our main problem is to make sure that these college courses required in the preservice education of teachers do justice to the essentials of conservation education.

Each of the St. Louis Teachers Colleges is conducting a program of in-service training and consultant service for teachers in service. Members of the faculties are released from a certain amount of teaching in order that they may carry on this work. Educational conferences and work shops for teachers are conducted. In these conferences and workshops, conservation, we think, gets its share of attention. Recently, on two occasions, we have provided conferences for our teachers conducted by the State Conservation Commission. The Missouri Conservation Commission also provides the services of two naturalists who go from school to school giving lessons on conservation to teachers and pupils.

We are trying to promote the correlation of our conservation programs and our elementary science programs with the participation of the schools in certain civic and community enterprises. Just now rat-control is a center of interest in St. Louis. Our newspapers are giving much space to the subject. In the schools we are showing a film, *Vandals of the Night*, and we have distributed among teachers a circular on the subject, *Questions and Problems that Arise in the Study of the Rat Problem*. We were amazed at the ramifications of the subject, such as: the teeth of rats; the intelligence of rats as compared to that of other animals; the omnivorous feeding habits of rats as compared to the carnivorous and herbivorous habits of other animals; the ability of rats to see at night; their high birth rate as compared to that of other animals; their natural enemies; and the uses we make of domesticated white rats and mice. Smoke elimination is receiving much emphasis in St. Louis as a civic and com-

munity enterprise, and we are encouraging teachers to use this as an organizing center for science, health and social studies lessons. Similarly, we are encouraging teachers to capitalize on the efforts of the city to improve its system of garbage disposal; to clear its river front and to restore the river to its former state of beauty and usefulness; to prevent the growth of weeds that pollute our atmosphere with irritating pollen; to eradicate mosquitoes; and to promote each spring a clean-up, paint-up, fix-up campaign. If pupils get the idea that we are not propagandizing and moralizing and verbalizing with them but rather that we are taking them along with us as public-minded citizens engaged in a very serious study of municipal and sanitary engineering, they will show more interest in these studies.

St. Louis, like other cities, is facing the problem of controlling vandalism among our misguided youth and adults. A dictionary defines a vandal as, "a ruthless plunderer, a wilful destroyer of what is beautiful and artistic." Here is where our guidance experts, our art teachers, our park and playground associations, our religious workers and all juvenile agencies cooperate with the conservation program.

The Division of Audio-Visual Education of the St. Louis Public School System is very much interested in conservation education and has acquired many films for use in the schools in the promotion of this work.

Finally, may I make mention of our new Course of Study in Science for the St. Louis Elementary Schools. In this Course of Study (St. Louis Public School Journal, Vol. 1, No. 2, Dec. 45) an attempt has been made to present a program of science for each grade in the schools. In order to make the science program more comprehensive a list of concepts has been recommended for each grade. In each grade these concepts are arranged under five headings: The Earth, Beyond the Earth, Living Things, Chemical and Physical Forces, and Man's Control of Nature. For each concept activities are recommended to develop it. Those who made the course of study have tried to see that a phase of conservation education is presented for each level of instruction in the schools.

Metal locator, to spot metallic foreign substances within the body, indicates the presence and orientation of the metal by visible and audible means. A primary coil creates an alternating magnetic field about a probe. Any hidden magnetic metal causes a current change in a secondary coil.

TECHNIQUES OF OUTDOOR EDUCATION

WILLIAM M. HARLOW

New York State College of Forestry, Syracuse University, Syracuse 10, N. Y.

The trend toward outdoor education appears to be so strong that within the next few years, increasing numbers of teachers will be asked to take groups outdoors for instructional purposes. Although much time has been spent in learning how best to teach within the confines of a school room, little or nothing is known by the average teacher on how to handle a group of thirty pupils outdoors. Let no one suppose that special techniques are not required for leading such groups in field and forest. In fact, teaching outdoors poses problem after problem which may stump most teachers trained by traditional methods. One teacher exclaimed "When the doors open, and I take my class outside, it seems to explode right before my eyes!" Realizing this situation, Dr. L. B. Sharp, Executive Director of Life Camps Inc., stated at a recent Camping Education Institute, "Research is needed on teaching methods for outdoor education." This statement has stimulated some thought on the subject, the results of which follow.

The only outdoor method known to many teachers is that of the "excursion" where teacher and pupils visit various local units such as the firebarn, dairy, or airport. With a class of thirty, the excursion is a very difficult affair to manage under field or woods conditions. First of all, only a few pupils have an adequate chance of seeing small objects (insects, flowers, etc.) which may be discovered. Those on the outside try to see by pushing in toward the center of the now compact group, or try drastically to improve their situation by crawling through a maze of legs to bob up suddenly in the center. Either device is disruptive to good attention, and things soon become "very unsatisfactory." Then too, it is amazing how far a group of thirty must be strung out along a forest trail to walk at all comfortably. Each person needs at least three or four feet of distance to separate him from the heels of the one before him. This means a line ninety to one hundred and twenty feet long, an impossible situation for bird observation, and even though trees and other plants won't fly away, the attention of the first of the group wavers or disappears while one waits for the rest to arrive. Explanations begun immediately leave those behind

"in the dark." The mechanics of handling such a large group under these conditions are inescapable. No one can do it properly, least of all a teacher whose training has been for indoor teaching. Successful forest or field excursions require a group of not more than fifteen pupils, and a teacher who has an extensive background of forest or outdoor lore.

Continued exploration on outdoor teaching methods will undoubtedly result in the discovery of techniques which teachers *can* use with ordinary-sized classes. Such techniques require careful planning before leaving the class-room. Both teacher and pupil must know what they are going to do when they get outdoors, and most important, they must have real interest and enthusiasm for the doing of it. When we go outdoors we go to "explore" and "discover," to "experience" that which we have read about.

Youngsters can be thrilled by stories of the old land surveyors who with hand compasses pushed their survey lines through trackless forest, or of mariners and airmen who use the compass to guide themselves and others over or through unmarked oceans of water or air.

Project: To discover or sense the fundamental factors of time and space, direction, and distance. In an air age, everyone needs to have a mature and developed concept of direction and distance. This can best be done by starting with the simple method of compass for direction, pacing for distance. In one hour an airplane can fly from three to four hundred miles or more. A child can never fully appreciate such speed until he has actually walked a mile with his own two legs.

Procedure: Before going out, divide the class into "survey parties" of three each. Issue to each party a hand compass, and have parties made up so that every child can watch the compass as you explain its use. Compasses should consist of a compass card bearing directions, and degrees clockwise from 0° to 360°; and a pivoted needle swinging above it. Point out first how to tell which end of the needle points north. The extent to which you explain that magnetic north and true north are not usually the same depends upon the level at which this material is being taught. When first introduced, deal with magnetic north only, since the following "exploration" can be done without reference to true north. Be sure that compasses are held level, and if iron or steel objects are at hand, it can be shown how the compass is attracted by them, and how important it is

to remove this source of error in the field. With the compass held level, have the pupils slowly rotate it to prove that it is the compass card bearing the directions, *not the needle*, which is moving. One teacher in training thought that the compass always pointed toward camp! Now ask that the compass be rotated so that the north end of the needle lies directly over the "N" on the compass card. The compass is now ready for use. Have each pupil imagine he is the size of an ant, and placed at the center of the compass. To go in any stated direction he merely follows one of the 360 "streets" radiating like the spokes of a wheel from the center. Inspection shows that North is zero, or three hundred and sixtieth street, whichever is most convenient, East is ninetieth street, South is one hundred and eightieth street, and West, two hundred and seventieth street. Good drill in arithmetic is now provided by asking what street "numbers" will be found at Northeast, Southeast, Southwest, or Northwest. This method of reading compass bearings clockwise from 0°–360° is called the "azimuth" method, (Arabian origin, meaning "the way") and is used by mariners and airmen[1] alike.

Now proceed to the center of as large a space outdoors as may be available and have each survey crew record the directions of a number of conspicuous objects located as far away as practicable. Spread the crews apart several yards from each other to avoid confusion, and take directions only to the nearest ten or fifteen degrees (small hand compasses). Before returning to the school room have each pupil pace at a natural walking gait a measured distance (100 feet is convenient) and record the number of steps required for each of three trips. Avoid having them pace together since they will tend to influence each other's gait. Having returned to the school room, have each one figure out the average length of his step to the nearest tenth of a foot. Three teachers in training asked at this point, "Do you divide number of steps into 100 ft., or 100 ft. into number of steps?" Each pupil is now equipped to measure distance and direction on the ground.

An area of woods and/or fields is best for the next exploration, but any available outdoor area may be used. The problem is that of the old time land surveyor, viz. with compass and pacing to lay out a rectangular piece of land, mark the corners

[1] See "Map Reading for the Soldier" published for one dollar by the *Infantry Journal*, Washington, D. C.

and return as nearly as possible to the original corner. Before going out explain carefully exactly what is to be done. Draw upon the board a small triangle with a dot in the center. This represents the starting point. Indicate that the first "leg" of the square is to the North 300 ft. or whatever distance you choose, and that the 90° angles are to be turned clockwise at each corner. have the class give you the directions of each of the other three sides. Have each pupil figure how many steps he must take to equal 300 ft. Verify the results. Number the members of each crew (1) (2) (3). Number one holds the compass. Number two goes ahead as far as he can be seen by number one who directs him right or left by *hand signals*. Allow no "hollering." Tell the pupils that hand signals and silence are "professional." Number two may be able to get to the first corner and still be seen, but in the woods this is rare. When number two is "on the line," number three paces the distance between the first two and records it. Number one meantime walks up and stands on the spot occupied by number two who now goes ahead. This process is repeated until number three in pacing between the first two gets to the calculated 300 ft. mark. Here and at successive corners, the three change jobs, in any manner desired so that eventually everyone has had a chance to "run compass," pace, and "anchor the line." The question is which crew will come back the closest to the starting point? All this is thoroughly understood before leaving the quiet of the class room (the wind may be blowing outside, or other noises may make attention difficult). When you get outside, assign each crew a different starting point. Scatter these around so that no two crews have the same lines to survey. It is to be hoped that you have done a little surveying of the tract previously so that you do not inadvertantly run some crew into a lake, ravine or other too hazardous or impossible obstacle! Also, if in the country have a care for sending crews across farm fences. Don't get the idea that such obstacles will stop these "young surveyors." You will only have some torn clothes to explain, to say nothing of broken fences to be mended. It should be explained that when an obstacle such as a clump of trees is encountered, the pacer counts steps up to it, side steps a sufficient distance and then goes ahead, side stepping back on to the line once more when the obstacle is cleared. The compassman is responsible to see that the pacer gets back on the line. Minor difficulties may be left to the ingenuity of the pupils

whose objective is to lay out as perfect a square as possible and get back to the starting point.

Having started your crews, you can now sit down on a log and wait for them to come back. However, it is a good plan to have a measured two or three hundred yards along the trail marked at each end. When the first crews come in, let them pace this distance to find out if their pacing error is plus or minus. Possibly there will be time for all of them to do this. For more advanced students, a triangular plot may be surveyed, or lines other than North, South, East & West may be used. Tell a crew to run one side at 75° and to figure out the other angles. Numerous other problems directly illustrative of arithmetical processes will suggest themselves. There will also be no question as to the quality of your instruction. If one or more of your crews wind up over in the next township, you will know that you didn't explain something well enough! With such explorations to supplement indoor work, it is predicted that interest in arithmetic and geometry will hit a new high. The equipment is simple, and there is no reason why any teacher with the proper school and community backing should not succeed with this method. In another article, ways of handling thirty pupils outdoors using a biological subject will be outlined.

FOR THE AIR-MINDED

Air Transportation, a new six-page leaflet, by Helen R. Blank, has just been published by Occupational Index, Inc., New York University, New York 3, N. Y. A valuable aid to ex-servicemen interested in air transportation, to vocational counselors, to students, and to all men and women who are air-minded, this abstract is available for 25¢, cash with order.

This concise leaflet evaluates Air Transportation as a career, its postwar prospects, nature of the work, qualifications, unions, preparation, entrance, advancement, earnings, number and distribution of workers. Listing selected references for additional reading, the leaflet also weighs the relative advantages and disadvantages of the air as a career job.

EUROPEAN HIGHER EDUCATION

With buildings destroyed, libraries looted, educational systems dispersed, European universities are courageously reopening with larger than pre-war enrolments. Holland has 21,000 students in higher educational institutions as compared with 15,000 before the war. Poland reports 100,000 candidates for 30,000 places available in Polish universities. Registration at the University of Paris is so high many students have been sent to provincial universities.

A STUDENT-MADE MICRO-PROJECTOR

KENNETH E. ANDERSON
University High School, University of Minnesota

AND

TENNY LODE
Student at University High School

During the summer session at University High, one of my students in Biology, undertook the project of designing and demonstrating a micro-projector for the class. We found it highly successful under low power, for observing stained slides of cross-sections such as the hydra, the earthworm, a dicot stem, and a monocot stem. We also used it for showing whole body structure in protozoans such as the paramecium and the amoeba. Under ideal conditions it was possible to see general body outlines and movements of live cultures of protozoans.

As a teaching device in Biology or General Science, the micro-projector helps the teacher to point out important structures that might be missed in study of a particular slide by an individual.

As part of the exhibit on "Aids in Teaching Science," Tenny demonstrated his micro-projector to teachers attending the summer session. Many of his listeners commented on the simplicity of the instrument. Tenny's description of the projector follows.

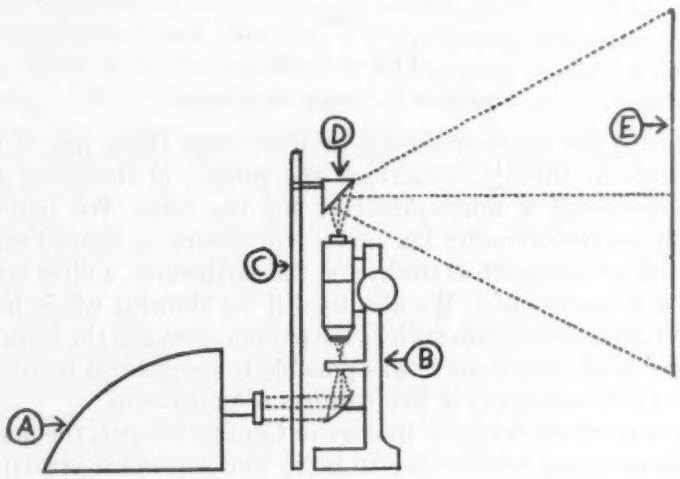
AN IMPROVISED MICRO-PROJECTOR

Biology teachers, as a whole, would find a micro-projector a very useful aid in teaching, but for budgetary reasons most schools cannot include this apparatus in their laboratory equipment. The advantages of the micro-projector are:

A. The teacher can easily point out the sections or parts of the slides to which he wishes the class to pay particular attention.
B. In many cases there will be only one slide of a certain specimen available, and time may be saved by placing the slide into the micro-projector, thus permitting the class to view it as a group.
C. The instructor may show the class some special process, such as the dividing of a one-celled organism, by placing the slide into the micro-projector, and explaining the process as it is shown on the screen.

Although most schools do not possess a micro-projector, one can easily be improvised from equipment which is usually available. The necessary pieces of equipment are:

A. A source of strong light, such as a motion picture or slide projector.
B. A microscope (preferably monocular).
C. A ring stand with clamp.
D. A right angle prism or mirror (preferably a prism).
E. A screen (a white sheet of paper may be used).



The light from the projector (A) strikes the concave mirror of the microscope (B) and is reflected through the slide. The image is magnified in the main tube of the microscope and is reflected on to the screen (E) by the prism (D) which is held in place by the ringstand (C). The eyepiece is left on the microscope.

SOME CHANGES IN MATHEMATICS AT OSU

Ohio State University's department of mathematics announced several personnel changes at the opening of the fall quarter.

Retiring from the department staff after 30 years' service is Professor Grace M. Bareis, who first joined the Ohio State faculty as a graduate assistant in 1906.

Miss Bareis, a native of Canal Winchester, took her bachelor's degree at Heidelberg College and her doctorate at Ohio State, graduating first in her class at Heidelberg. She is a member of Sigma Xi and many other technical and scientific societies and has been active in church, university, and community affairs.

New appointments to the staff include: Marshall Hall, formerly on the staff at Yale University, and Howard H. Alden, formerly of the University of Wyoming faculty. Hall, who comes to OSU with the rank of associate professor, served in the navy as a lieutenant commander. His field of specialization is algebra and group theory. Alden, an assistant professor at OSU, is a specialist in mathematical applications in engineering.

THE ART OF SUMMATION

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In its simplest form this art consists in *counting* the items of a collection by matching them with the numbers—one, two, three, · · · . If two, or more, groups are merged into one, the resulting number can be obtained by the same procedure. The use of addition combinations is, however, a labor-saving device. Effective aid is also derived from observing, and recording, the results of *repeated addition*. The fact that five four's make 20 e.g., is embodied in the statement,

$$5\times 4=20.$$

Problems in mensuration readily lend themselves to the use of repeated addition. A rectangle 4 inches in length e.g., contains 4 inch-centimeters, per centimeter of width. A width of 3 cm. yields, therefore,

$$3\times 4=12 \text{ in. cm.}$$

Arithmetic progressions are summed by matching the regular

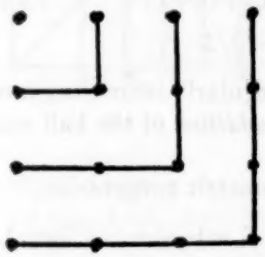

FIG. 1

increase in one direction with the equally regular decrease in the opposite direction. Thus, if,

$$(1)_1 \qquad S=1+3+\cdots 2n-1,$$

we have also,

$$(1)_2 \qquad S=2n-1+2n-3+\cdots +1,$$

so that,

$$(S+S)/2=S=n+n+\cdots n, \quad \text{to } n \text{ terms},$$
$$=n^2,$$

which is intuitive for $n=4$ in Fig. 1.

The "leveling" effect of "matching" equations $(1)_1$ and $(1)_2$ is emphasized in Fig. 2, where A, B, and C represent, respectively, the direct sequence $(1)_1$, the reverse sequence $(1)_2$, and the half-sum of the two, for $n=4$.

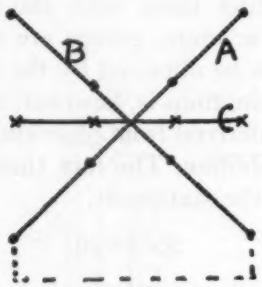

FIG. 2

In general, if,

$$\begin{aligned} S&=a &&+a+d &&+\cdots a+(n-1)d=L,\\ S&=L &&+L-d &&+\cdots +a,\\ 2S&=(a+L)+(a+L)+\cdots +a+L,\\ S&=n(a+L)/2. \end{aligned}$$

The summation of regularly increasing numbers reduces, therefore, to the *repeated addition* of the half-sum of the first and last numbers.

In summing a geometric progression,

$$S_n=1+\tfrac{1}{2}+\cdots \tfrac{1}{2}n-1,$$

e.g., the effective device is to multiply by the common ratio, which is 2, reading from right to left. Thus,

$$2S_n=2+1+\cdots \tfrac{1}{2}n-2$$

so that, by subtraction,

$$S_n=2-1/2^{n-1}.$$

In the general case,

$$\begin{aligned} S_n&=a+ar+\cdots ar^{n-1},\\ rS_n&=ar+ar^2+\cdots ar^n,\\ S-rS_n&=a-ar^n, \end{aligned}$$

$$S_n=(a-ar^n)/(1-r)=$$

If $r=a/(a+b)$, a, b, positive integers,

$$r^n=a^n/(a+b)^n<a^n/(a^n+na^{n-1}b)$$
$$<1/(1+nb/a),$$

and since nb/a increases indefinitely with n,

$$Lr^n=0, \quad \text{and hence,}$$
$$LS_n=a/(1-r), \quad \text{as} \quad n\to\infty.$$

Paradoxically, therefore, the "sum" of an "infinite" number of terms involves a simpler computation than does a finite sum.

Summation procedure may also be illustrated by computing the area, A, under the "curve" $y=x$, $x=a$, to $x=b$. In Fig. 3,

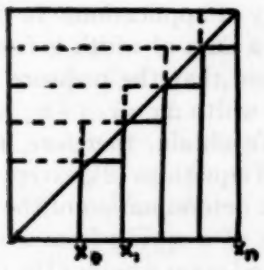

FIG. 3

the interval a to b is divided into n equal parts, each of length $\Delta x=(b-a)/n$. Letting $a=x_0$, $b=x_n$, and denoting the intermediate points of division by $x_1, x_2, \cdots, x_{n-1}$, it is evident that the sums of the "inscribed" and "circumscribed" rectangles are, respectively,

$$(2) \qquad A_n=\sum_{i=0}^{n-1} x_i\Delta x, \qquad B_n=\sum_{i=1}^{n} x_i\Delta x.$$

Since,

$$(3) \qquad L(B_n-A_n)=L(x_n-x_0)\Delta x=L(b-a)^2/n=0$$

we have,

$$LA_n=LB_n,$$

where L denotes the limit as n increases indefinitely. Moreover,

$$A_n < A < B_n, \tag{4}$$

so that the common limit is A, which may be computed, therefore, by finding the limit of either A_n or B_n. Selecting the former, we have,

$$A_n = \sum x_i \Delta x = \Delta x \sum x_i = \Delta x \cdot n(x_0 + x_{n-1})/2,$$

since the x_i form an arithmetic progression and $i = 0, 1, \cdots, n-1$. Hence,

$$A_n = (b-a)(x_0 + x_{n-1})/2,$$

and since

$$x_0 = a, \quad \text{and} \quad Lx_{n-1} = L(x_n - \Delta x) = x_n = b,$$

$$A = LA_n = L \sum x_i \Delta x = (b^2 - a^2)/2. \tag{5}$$

Equations (2) to (5) are evidently numerical and therefore available for a variety of applications. In finding e.g., the force of water pressure on a dam of width w from a depth $x = a$ to a depth $x = b$, we assume that the pressure factor $62.4x$, over a strip of length w and width $\Delta x = x_{i+1} - x_i$, is constant and either $62.4x_i$ or $62.4x_{i+1}$. We obtain, therefore, two sums which are identical with those of equations (2), except for the factor $62.4w$.

In like manner, the determination of the work required to increase the elongation of a spring from $x = a$ to $x = b$, involves two sums which depend upon whether the force over a "stretch' $\Delta x = x_{i+1} - x_i$, is taken to be kx_i or kx_{i+1}, where k is a constant. In computing the distance traveled between $t = a$ and $t = b$, by an object whose velocity is gt, we again obtain two sums which depend upon whether the velocity over a time interval $\Delta t = t_{i+1} - t_i$, is taken to be gt_i, or gt_{i+1}. Since it is evident in each instance that the entity in question lies between the "inscribed" and the "circumscribed" sums, we obtain the following results which correspond to equation (5),

$$F = (b^2 - a^2)/2 \cdot 62.4w,$$

$$W = (b^2 - a^2)/2 \cdot k,$$

$$D = (b^2 - a^2)/2 \cdot g.$$

In Fig. 3, the doubling effect of symmetrization by reflection in $y = x$, reveals that $\sum 2x_i \Delta x$ "adds up" to $b^2 - a^2$, except for the "small squares" which are "strung along" the "mirror." Thus,

$$D_n = b^2 - a^2 - \sum 2x_i \Delta x = \sum \Delta x^2 = (b-a)^2/n,$$

so that,

$$LD_n = L\sum \Delta x^2 = 0,$$

and hence,

$$L\sum 2x_i\Delta x = b^2 - a^2 = x^2\Big]_a^b. \tag{6}$$

As n increases indefinitely, the "small squares" which are n in number become more and more numerous to provide the "footing," $x_{i+1} = x_i + \Delta x$, for a correspondingly greater number of rectangles. At the same time, the area of each, Δx^2, varies inversely with n^2. Hence $\sum \Delta x^2 = n\Delta x^2$, varies inversely with n and approaches zero as $n \to \infty$. The "small squares," therefore, do not "disappear" in the limiting process, but simply "fail to add up."

If L and $\sum$ are concentrated into an elongated S, and if the subscript i is understood, but the range of summation is made explicit, equation (6) becomes,

$$\int_a^b 2x\,dx = x^2\Big]_a^b.$$

Thus,

$$L\sum{}^{b}_{a} = \int_a^b,$$

provided that the summands are of the form, $f(x_i)\Delta x$, where $\Delta x = x_{i+1} - x_i$. The new (old) S suggests summation, but since it replaces L, as well as $\sum$, it carries a connotation of limit which is intensified by the substitution of dx for Δx.

Since the combined procedure yields the *entire* area, the terms integral, integrate, and integrand are self-explanatory if we recall that the Latin *integer* is derived from the prefix *in* and *tangere*, to touch, and means, therefore, untouched, or *whole*. Making whole in the integration sense is, therefore, summation *plus*. The limiting process produces the "final victory" by eliminating "pockets of resistance," such as the "small squares" in Fig. 3.

High-frequency induction heater, that widens the scope of electronic heating, is in a steel cabinet less than four feet square. It can be used for brazing, soft soldering, fusing, hardening, annealing, tempering, as well as for other purposes. It has two water-cooled oscillators and six rectifiers.

SOME WAR-TIME DEVELOPMENTS IN CHEMISTRY

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IV. MEDICINALS

Modern warfare has greatly stimulated medical research and the advances which have resulted are definite gains in the struggle against disease. World War II has made many remarkable contributions to medical science because of the incentive produced by the large number of individuals involved, the intensity of the struggle and the great variety of needs in the world-wide battle lines. These advances are now being adjusted to the needs of civilian populations.

Penicillin is now a name which has become familiar in our households, where it is sometimes referred to as "the wonder drug." It is produced from a mold (***Penicillium notatum***) which is somewhat like that seen upon stale bread. Commercially it is grown on the surface of broth media in small containers or by deep fermentation in the sterilized material of large tanks. After several days growth under rigid control the penicillin is removed and subjected to careful processing under sterile conditions. Huge plants for the production of this drug have been built in the United States and Canada at a cost of $20,000,000. The total production is about 9 pounds per day. The amount available in April 1946 was estimated at 2,178,175 billion Oxford units,[1] three times the supply available in December 1945, which in turn was nearly double the production of the preceding January. Foreign demand is largely met by American manufacture and, in spite of the rapid increase in production, the total demand is about 12–15% above the amount available. At first all the product was used in the armed forces, but now it is available for general use. The cost at first was $20 per 100,000 Oxford units, but in August 1945 the same amount sold for 59 cents. The drug is effective against pus-forming bacteria and infections of the blood. It is used in the treatment of pneumonia, meningitis, gas gangrene, infections, venereal diseases and other

[1] This is a technical measure of the potency of the drug proposed by a group of doctors at Oxford, England who were among the first investigators of penicillin. It has been defined as "that amount of penicillin in 1 ml which when placed in a porcelain cup will completely inhibit a test strain of *Staphylococcus aureus* in a zone 24 mm wide."

afflictions. It may be administered by mouth, but this is wasteful because of destruction by hydrochloric acid in the stomach. Usually administration is by intramuscular injection of sodium salt in sterile normal saline solution. Promising results have also been obtained by the use of benzyl ester, which may be taken by mouth.

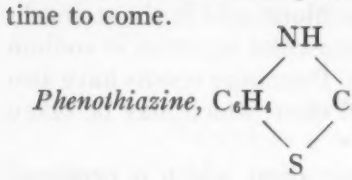
Streptomycin is another antibiotic agent which is produced by a mold (actinomyces) in much the same manner as penicillin. It is best administered by intramuscular injection. It acts upon certain bacteria which are not attacked by penicillin and is the best known drug for the treatment of tularemia. It has shown promise in combating influenzal meningitis, urinary and intestinal infections, tuberculosis and other diseases. The supply of this drug is still insufficient even for military needs, but large plants are rapidly increasing the amount available. In April 1946 there were available 29,900 grams, a 10% increase over the preceding month.

Gliotoxin is a potent antibiotic substance which is produced during the growth of a certain fungus. Its activity in the control of the growth of bacteria exceeds that of penicillin and similar substances. It is being studied to determine its structure.

Subtilin is another antibiotic which is extracted from bacillus subtilis. Test tube experiments indicate that it kills tubercle bacillus, but is only slightly toxic to living tissue.

The name *sulfa drugs* is applied to a group of compounds which have become very useful in medical practice. The mother substance of the group is sulfanilamide ($NH_2:C_6H_4:SO_2:NH_2$) which is useful in the treatment of erysipelas and blood poisoning. The properties and effect of the drug are modified by replacing one of the hydrogen atoms in the final NH_2 group by a residue of some other compound. As for example pyridine (C_5H_5N) is attached to sulfanilamide to form sulfapyridine, $NH_2:C_6H_4:SO_2:NH:C_5H_4:N$. By making other substitutions some 1300 compounds have been prepared and tested for their medicinal value. A few of these have shown great promise, as for example sulfadiazine, $NH_2:C_6H_4:SO_2:NH:C_4H_3N_2$ which has shown such great usefulness in the treatment of pneumonia, abscesses and infections. During the war period the use of the sulfa drugs increased greatly, both in the amount used and in the number of compounds employed. It is stated that the combined production of sulfa drugs in 1943 exceeded 4,930 tons.

It is doubtful if consumption will reach this quantity for some time to come.



use has increased greatly, especially as a live-stock remedy The U. S. Department of Agriculture refers to this compound as a "wonder drug that kills more kinds of internal parasites in more kinds of animals than any other known chemical." The statement has been made that its use in killing internal parasites in livestock saves $10,000,000 annually. It has also been useful in fighting the codling moth and mosquito larvae, and in disinfecting seeds and soil. More recently it has been found effective in the treatment of some intestinal parasitic infections in man.

Thiouracil, an organic compound containing sulfur, has been shown to be beneficial in the treatment of sufferers from toxic goiter. In about 90% of the cases so far studied, this drug reduces the abnormally high metabolic rate and improves the clinical condition of the patient before an operation is performed The results of the operations have been excellent, though there is still some risk in the use of the drug, due to the occasional depressing effects upon the blood-forming organs.

Rutin is a glucoside which has been made available at the Eastern Regional Research Laboratory of the U. S. Department of Agriculture. Its chemical formula is $C_{27}H_{30}O_6 \cdot 3H_2O$. It is obtained by alcoholic extraction from flue-cured tobacco or better from green buckwheat. The purified drug forms bright yellow crystals which melt at 192°–196°C. When taken in capsules by persons suffering from capillary fragility due to high blood pressure there is a gradual return to normal within two months. Unfortunately the improvement does not seem to be permanent unless the treatment is continued. The drug has given clinical evidences of its effectiveness in preventing retinal and cerebral hemorrhages and apoplexy resulting from high blood pressure.

A new compound which reduces high blood pressure is being developed. It is a derivative of isopropylamino ethanol and is referred to as 0-4,277. It may be taken through the mouth or injected either intravenously or intramuscularly. When injected into animals, a half milligram per kilogram of body

weight reduces the mean arterial blood pressure by 50–60 mm. of mercury. The effect lasts for 1–4 hours. The reaction seems to be produced by stimulation of the mechanism for depressing pressure within the blood vessels and not by its effect upon the muscles which surround the vessels. If further study of this compound continues to produce favorable results, it will provide relief from many afflictions connected with excessive blood pressure.

Malaria has been called the most widespread major disease since it affects nearly half of the population of the earth. It became a major medical problem particularly when the armed forces of the United States went into tropical areas and the supply of antimalarial drugs (quinine and atabrine) was limited. The Office of Scientific Research and Development set up an elaborate campaign to provide a better remedy for malaria. Work was conducted in many universities, hospitals, clinics and in the army and navy. The organization of this scientific effort was an outstanding accomplishment, second only to the group which produced the atomic bomb. Four years work and an appropriation of $7,000,000 were employed in this scientific campaign. About 15,000 preparations were made and tested, first on lower animals (chickens, ducks, etc.) then the most promising were tried on human volunteers from penitentiaries and camps of conscientious objectors. Two especially promising compounds are now being tested in quantity in areas in which malaria is prevalent. These are known by their survey numbers as SN7618 and SN13,276. The former is a chemical derivative of quinoline (C_9H_7N). It is reported to be more rapid, more active and, in the small doses necessary for treatment and suppression of malaria, it has less disagreeable side-effects than quinine or atabrine. Administration of SN7618 for one or two days is said to effect a cure for the type of malaria known as falciparum, which is sometimes fatal. It does not cure the relapsing type of malaria (vivax) but it gives relief in a third the time required by either quinine or atabrine. A dose of 0.3 gram once a week is sufficient to check the attacks.

The drug known as SN13,276 is chemically related to plasmochin, which, in turn, is a complex derivative of quinoline. It has been known for some time that plasmochin has curative effects on malaria, but it is a dangerous drug to use because it produces serious disturbances in the blood. The new derivative of plasmochin has few of these toxic effects and seems to be a

specific cure for vivax. It is possible that these two new drugs will be able to bring permanent relief to the millions of malaria sufferers as soon as the experimental phases of the work are completed and the drugs are available for general use.

Para-amino-benzoic acid has given favorable results in the treatment of louse-borne typhus fever and Rocky Mountain spotted fever. It is to be hoped that further study will prove that this drug will be effective in the treatment of these dread afflictions.

The influenza vaccine which was used successfully in military service is now available for civilian use. It is said to be effective against certain types of influenza, but probably not all types.

Two new drugs have shown promise in the treatment of sleeping sickness. The one known as 70-A (para-arsenoso-gamma-phenyl butyric acid) is active in the early stages of the disease only. Melarsen oxide (para-arsenoso-phenyl-melamine) is effective in both the early and late stages.

Two new antispasmotic drugs give promise of usefulness. Both are highly complex organic compounds. The one called *amathone* is highly effective in relieving pain caused by ureteral stones or such processes as the use of a catheter in the ureter. The second drug, known as *tridione* is more effective than phenobarbital in controlling induced convulsions in animals. Its beneficial effects in the treatment of certain forms of epilepsy are said to be "dramatic."

Heparin is a blood anticoagulant which is present in muscle, liver and lung tissue. It was discovered in 1916 and is extracted from liver and has been used to prevent the coagulation of blood following operations and to check the formation of blood clots within the circulatory system. Its use has been much extended during recent years to prevent thrombosis with its all-too-common fatal results. Recently it has been used successfully to prevent the development of gangrene following severe frostbite. Gangrene formerly necessitated amputation. It is caused by the formation of a clot which shuts off circulation. By injecting heparin within 48 hours, circulation is maintained and no gangrene develops.

Dicoumarol, discovered in 1940, is another anticoagulant, which may be extracted from spoiled sweet clover hay. Its effect is similar to that of heparin although there is a marked difference in both time and duration of response. The injection of heparin is followed by an immediate response but the effect lasts

only for 1–4 hours. The injection of dicoumarol shows no initial response for 24–72 hours, but the duration of the effect is 2–26 days. The use of both drugs together is recommended. There is danger of producing hemorrhage, but this is quickly checked by transfusion of fresh whole blood or plasma. Both heparin and dicoumarol are complex organic compounds whose structural formulas are known. Dicoumarol has been made synthetically; it is cheaper than heparin and has some advantages since it may be administered either by injection or by mouth and the effect lasts much longer.

Allergies have been among the most annoying factors in modern life. It has recently been pretty well proven that many symptoms are due to the liberation of histamine ("H substance" from the tissues. Acting upon this theory a complex protein derivative, called hapamine, has been used to cause the neutralization of the "H substance" which is released by the tissues. Favorable results have been obtained in such difficulties as hives, dermatitis, eczema and even in some cases of hay fever and asthma. The problem has also been attacked by using synthetic antihistamine compounds, such as the benzhydryl ether derivative known as benadryl. This new preparation is effective in certain cases and its toxidity is low. While these results are to be regarded as preliminary they seem to indicate that progress is to be expected in relieving allergic reactions.

A new remedy for arsenic poisoning has been found. Chemically it is 2,3-dimethylcaptopropanol but since it was first used in England as a therapeutic agent against the effect of war arsenicals, especially lewisite, the name *bal* (British anti-lewisite) has been given to it. Extensive tests have been made both in England and in this country. The results are encouraging and it is likely that this material will become valuable as a remedy for various types of arsenic poisoning. Encouraging results are also reported from the clinical trials of bal in the treatment of mercury poisoning.

V. Health

Disinfectants and *insecticides* are of particular importance in the interests of public health not only because they aid in the control of disease, but also because they contribute to the production of our food supply by the destruction of parasitic forms of life. In time of war these phases of life have been carefully studied and material progress has been made. One of

the most significant developments of the past few years has been the production of the substance called *DDT*. This name is derived from its chemical designation, dichloro-diphenyl-trichloro-ethane. This compound which is made from chloral and monochloro-benzene has been found to be highly toxic to bedbugs, mosquitoes, lice, flies, fleas, cockroaches, codling moths, Japanese beetles and many insects destructive to food and ornamental plants. This insecticide was first used entirely in the armed forces, where it was credited with the eradication of both body lice and the resulting typhus and relapsing fevers. Late in May 1945 WPB authorized the use of limited amounts for the control of destructive pests of food crops. As the manufacture of DDT increased in amount, it was employed for the destruction of cattle grubs, flies, corn earworms, corn borers, sugar cane borers, grasshoppers, crickets, gypsy moths, forest insects and many other pests. Areas endangered by infantile paralysis were sprayed or dusted in the hope that the destruction of insects would check the epidemic. Warnings have been given, however, against the promiscuous use of DDT because of the danger of destroying beneficial insects such as the honeybee and the lady bird beetle. It has been shown that a 0.5% solution produces symptoms of poisoning when applied to young rabbits and that the application of a 5% solution generally produced fatal poisoning of rabbits both young and mature. The effects upon other forms of wild life and upon man are not yet certain. It is estimated that in the fall of 1945 the United States was manufacturing DDT at the rate of 1,500 tons per month.

Several other insecticides have received attention. In Germany difluoro-diphenyl-trichloro-ethane (called *gix*) was found to be more effective than DDT, but it is much more expensive. The U. S. Department of Agriculture has tested TDE (tetrachloro-diphenyl-ethane) which is similar to DDT but it is not available in quantity. In England the compound hexachloro-cyclo-hexane ($C_6H_6Cl_6$) has shown great promise. From its formula it is called 666 and the gamma isomer is known as *gammexane*. It is a stable compound, so it may be sprinkled on a hot surface when it produces a toxic smoke. It is also used as a dust or spray in an emulsion. Tests indicate that it is about five times as toxic as DDT for some pests, but less toxic for others. It is said to be 150 times as effective as sodium arsenite in the destruction of locusts. In the early summer of 1946 25 tons of gammexane were sent to Sardinia to check the serious

invasion of locusts which threatened to destroy all plant and vegetable life on the island.

A clever device for dispensing insecticides has been made for the armed forces, but is now available for general use. It is a so-called "bug bomb," a steel container filled under pressure with an insecticide like pyrethrum and oil and freon gas. The insecticide is discharged as a fine spray, which is efficient in killing insects but harmless to man. This principle has also been used for the distribution of insecticides from airplanes. A much wider coverage is obtained than was possible by former methods.

Repellents, closely affiliated in use with insecticides, have been studied intensively and several new synthetic preparations have been tested in the armed forces. Perhaps the most promising repellent so far made known is dimethyl-phthalate. It is safely applied to the skin of man and is effective in repelling mosquitoes. When applied to the outer garments it protects against chiggers and to some extent against wood ticks. A mixture of dimethyl-phthalate, indalone and 2-ethyl-hexanediol is especially effective in repelling mosquitoes and biting flies. Another repellent, benzyl benzoate, when applied to the clothing gives protection against mites.

New poisons for rodents have become imperative because of the shortage of the customary poisons, strychnine and thallium. The increase in rat population has threatened the food supply and intensified the danger from disease. Two new poisons have been prepared: (1) known as No. 1080 is *sodium fluoroacetate;* it is inexpensive, effective in killing rodents, but highly toxic to cats and dogs and presumably also to beneficial wild life and man. (2) An organic compound alpha naphthyl thiourea, called *antu*, is fatal to rats but harmless to man and dog.

Progress in biochemistry, especially as it concerns itself with a study of nutrition and metabolic diseases, will be greatly enhanced by the fact that heavy carbon C^{13} is now available in considerable quantities at a reasonable price. This will permit its use as tracer element, permitting the study of metabolic changes in the body both in health and in disease. The carbon of commerce contains only 0.7% of this heavy isotope, but two new plants of large capacity are being built with the view of increasing production a thousand fold. One of the plants is capable of producing 500 g. a month and the price is expected to drop from $400 a gram to $40. The cyclotron has made possible the

production not only of radioactive carbon but also of other elements such as hydrogen, nitrogen, sulfur, and phosphorus. Much work has already been done with the use of radioactive phosphorus in the treatment of malignant growths and serious blood diseases. One of the most valuable by-products of the atomic energy research will be the production of large quantities of tracer elements which can be used in the study of the normal processes of nutrition in the human body as well as the perverted developments which result in cancer, diabetes, diseases of the teeth and bones and many other maladies. On August 2, 1946 the United States Government made the first sale of such material to a cancer hospital. It consisted of a millicurie[2] of C^{14}, an intensively radioactive form of heavy carbon which was formerly produced in minute amounts in the cyclotron. The availability of these tracer elements should make it possible in time to determine the cause of many diseases. When this has been accomplished, then it should be much easier to discover means of effecting a cure.

Vitamins and *hormones* are vitally connected with health, growth, and the control of disease. As a natural consequence much attention has been given to these essential factors. The demand for vitamins, first prepared from natural sources, has increased at a rapid rate. This fact has stimulated the production of synthetic products and in less than a decade an industry of major proportions has grown up. The annual production of these synthetic compounds is said to total as much as 1250 tons and their purity has steadily increased. Research is continuing at a lively rate and new developments are being announced almost daily. A few will be mentioned here.

Two new derivatives of vitamin B_6 (known as pyridoxine $C_3H_{10}O_3N$) have been recently discovered. They are *pyridoxammine* and *pyridoxal*, which are more active bacterial growth promoting substances than the parent substance. Their chemical structures have been determined—the first step in the synthesis of such compounds.

A recent improvement in the production of vitamin C has been described. The new method is shorter than the old one and uses as raw material the solid beet pulp which remains after sugar has been extracted. Since vitamin C promotes the healing of wounds, this new process has been particularly useful during

[2] A unit of radioactivity, which may be defined as the quantity of a radioactive substance which produces as much emanation as one milligram of pure radium.

the war years. An accurate method for the assay of vitamin C has recently been perfected. This will be useful in the study and control of this important vitamin.

Vitamin H, known as ***biotin***, is a bacterial growth factor which has been shown to be a derivative of thiophene-valeric acid. It has been prepare synthetically. It is important in cell metabolism and probably also in fat synthesis. It has a curative effect on the induced skin disease known as "egg-white injury."

The rapid progress of vitamin studies is graphically shown by a recital of cost figures. In 1935 vitamin B_1 cost $300 per gram; in 1944 it sold for 20 cents a gram. Vitamin B_2 sold for $17.50 per gram in 1937 and in 1944 for 28 cents. Vitamin B_6 brought $12 a gram in 1938 and in 1944 it sold for $1 per gram. Vitamin C sold for $2 a gram in 1935 and for 3 cents a gram in 1944. Nicotinic acid, sometimes called niacin, the antipellagra factor of vitamin B_1, cost $35 a gram in 1937 but could be bought in 1944 for $3.63 per gram.

A new pituitary hormone has recently been isolated. When it is present in the blood it stimulates the production of serum proteins which contain antibodies that are essential in the fight against disease.

Surgery has been vastly important in time of war, especially in the treatment of wounds and in the rehabilitation of the wounded. During the World War I the advent of the Carrel-Dakin solution and its accompanying technique in treatment of the deep wounds and injured joints were regarded as among the most important contributions to modern medical practice. Early in World War II great reliance was placed on the use of sulfa drugs and penicillin to prevent infection. Later it was concluded that these drugs needed to be used along with thorough surgical removal of all dead tissue in order to prevent the development of infection. These skillful treatments along with the prompt administration of blood plasma or the transfusion of whole blood have made a marvelously low record of fatalities among military casualties.

Curare, a drug estracted from a South American plant and known for many years in that region as "flying death," has recently shown promise as an anesthetic. It has a marked selective action, affecting, in order, the muscles of the throat and neck, muscles of the extremities and finally, (or not at all) the diaphragm. There has been reported no damage to the tissues of internal organs. It has been successful in softening the effect of

shock in psychiatric patients and as an anesthetic for the production of complete muscular relaxation without resort to deep anesthesia. It is most useful in abdominal operations. Curare is best used with other anesthetics especially cyclopropane; nitrous oxide, ethylene, and pentothal may also be used. Neostigmine is an effective antidote for curare.

(*To be continued*)

CHILDREN BENEFIT

ANGELO PATRI

The children are the most important group in the community, the school the most important institution, the teacher the most important worker. Of course, everybody says but no group in sufficient majority acts that idea out in terms of practical help.

The children in school today will have a voice in running the country in a few years and on the quality of their thinking, on the strength of their behavior, in the power of their souls, the fate of this Nation, perhaps of the world, must rest. That thought ought to make us all . . . consider seriously what our children are getting out of our schools.

To begin with it must be known that the teacher in the classroom is the whole of school to the children she leads. Good teachers are not different in these respects. They must have salaries that maintain them on the level of the best citizens, best meaning in character, contributions to the general welfare, service to American ideals. That is not too much to ask.

Above all, above good salaries, above living conditions and above social recognition, teachers must have spiritual freedom, the freedom that allows their minds to spread their wings, their souls to expand. . . .

If your schools are not just what you would like, the reason lies in your lack of support for the school you want. Don't blame the teacher. Blame your own failure. Give your teacher fine leadership, good equipment, good pay, an honored place in the community and that teacher will repay the cost in what she gives to just one child in the classroom.—Reprinted from *The Washington Star*.

SCHOOLS AND THE WAR

Accomplishment of victory in World War II demanded more highly trained men, both from a military standpoint and a technical standpoint, than in any previous war in the history of man. The schools and colleges met this demand for men of highly technical and professional training for use in industry and in the military service. With the outbreak of hostilities, the educational facilities of the country with little delay were adjusted to the needs of the United States Army. By close coordination between the Army and these institutions, we were able to establish programs of instruction and training to provide the Army with the vast number of technical specialists it required.

I believe that each individual who took part in this program should have the satisfaction of knowing that by his substantial contribution and cooperation the duration of the war was undoubtedly shortened to a measurable degree.—*Brehon Somervell, General, U. S. Army.*

A TENTATIVE RECONSIDERATION OF PRINCIPLES UNDERLYING THE HIGH SCHOOL COURSE IN PHYSICS

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During the last twenty years, much attention has been given to revising high school curricula. In the process, physics has not fared too well. In this paper, there are three main divisions. The first deals with certain aspects of physics as it fits into the high school curriculum. The second part deals with teaching problems; the third with the mathematical content of the high school physics course.

The writer's viewpoints are the result of experience over a period of sixteen years in teaching general science, biology, chemistry and physics. As teacher, he has observed, from intimate contact, the adolescent mind in its attitudes toward and manner of approach to the subject matter of physics, through stages of mental development from the junior high school general science age, through the first year of college physics in Navy V-12 teaching. Not only have sciences been taught over the full range of adolescent ages, but also over a wide variety of circumstances, from the small to the large high school, with a range in laboratory equipment from the most meager to the best possible obtainable equipment to be afforded in both a large departmentalized high school and in a college.

The immediate occasion for the writing of this paper begins with the fact that the outbreak of World War II found the Army and Navy appealing to the schools to stress mathematics and physics; within a year or so, the colleges and universities of the land were taken over for the purpose of giving the necessary background of mathematics and physics to wage a mechanized war against forces of human extermination. War-weary, we find the educational systems confronted with the advisability of remedying the situation with reference to physics and mathematics that pertained in the 1930's, which the outbreak of war revealed to have been direly inadequate.

The outstanding fact of the 1930's with reference to physics is that the subject was virtually relegated to the background in the cirriculum. Social sciences were being stressed above the pure sciences in hopes of solving social problems contingent upon the great depression. President Jas. D. Hoskins of the

University of Tennessee remarked to the writer in 1942 that the reason for physics being practically dropped from the curriculum was "because it is hard." Definitely, many means of making it easier were resorted to. Examination of the newly published high school textbooks of the period shows a tendency to tone down the subject matter somewhat, with efforts to link physics with the environment, in order to arouse the student's interest in the subject. We might observe that the subject matter was reduced while the trend of activities of civilization was increasingly toward a mechanization applying the principles of physics. We are faced with the educational problem, that "modern man" lives in mind apart from and out of step with the world he has constructed about him, to the extent that he is collectively ignorant of the radio's workings, and that of electricity, operation of the airplane in the "air age," and so forth. This means that he is ignorant of physics, while physics, as the key to the material world of today, definitely holds a vital place in the intelligent adjustment of a sane population to its environment.

Regardless of at whose door we may be inclined to lay the blame, or to what cause we attribute the near-debacle of physics education, the remedy is certainly not in toning physics down to the extent of near-elimination, which is similar in principle to getting rid of the valuable dog because he has fleas. Instead, we eliminate the fleas. Our problem is similarly to rid physics education of the fleas, and retain physics as a member in good standing in the high school curriculum.

The scope of this discussion is not pretended to cover all the problems involved in presenting physics, nor assume the proportions of a treatise on methodology. *Certain aspects of the problem as a whole are being pointed out as a suggested field for investigation and consideration.* The writer does *not* pretend to have arrived at final and definite solutions, but holds suspended judgment until scientific data can be secured to take the place of some hypotheses herein contained. Aspects of the problem as a whole are to be pointed out as a suggested field of consideration, investigation and proof.

These aspects are:

1. Physics is not popular. The public remains, as a whole, densely ignorant of its existence, even; much less does it know what comprises the field of physics. This presents an almost insurmountable difficulty for the administrator, who is under

constant necessity of giving the public an account of his administratorship.

2. Physics presents a problem of content-mastery in a type of thinking which not only deals with sensory percepts of a very concrete environment, but also with abstract concepts which, while closely related to the sensory percepts of the concrete, are yet quite abstract to the beginner. This poses a difficulty calling for the most earnest and intense effort of the teacher, and of the pupil; a type of effort which, frankly, often ricochets back to the administrator who must fit the curriculum to an over-all plan, involving social aims, student attitudes, and an educational philosophy of some sort.

3. The abstract nature of physics must be related to "life"; the liaison here has hardly been effected. Can it be?

4. Physics runs into difficulties with educational philosophies of some types. It is a subject that has laws unto itself, and its teaching presents problems because of the incorrigible inadaptability of physics to any set of regulations imposed from without physics itself. But since the schools increasingly are organized and administered according to general, over-all philosophies, physics teaching should be adjusted to them, if retained.

5. Physics presents difficulties because of its mathematical aspects.

These are the spots on the dog where the fleas hide. The remainder of the discussion will take the nature of tentative suggestions for dealing with the spots, pointing to possibilities for research, and experimentation in some cases the writer can find no record of having been done. Some suggestions may partake of the flavor of what is believed by the writer to be practical common sense which has been overlooked because of the fervor to be considered professional in a day of perhaps overprofessionalization.

Relation to Life and Community Setting

Here let us consider aspects numbers one and three above, first viewing the place physics should hold in the State of Tennessee as a whole community.

As a community, the State is composed in part of small communities which run the full gamut of degrees of development, beginning with the simplest communities, where ignorance is at its primordial and extreme development, or rather, lack of development. The aspects of the State so played up in many of

the viewpoints and writings of onlookers in other parts of the United States can certainly be found in some communities of the State. On the other hand, and this is a fact often overlooked, these communities are in close proximity with other communities which approach a high degree of economic development, enlightenment, and opportunity for advancement. It is usually a short distance from one extreme type to the other. Thus the Alcoa aluminum plants, not to mention Oak Ridge, draw many workers from communities of the remote type, where we may find total ignorance of physics and chemistry. and even opposition to science education, due to lack of knowledge and understanding of these fields. This sets us in locating both chemistry and physics as vital problems in the field of education, in a State which is rapidly changing from agricultural to industrial economy based on electric power; and in agriculture alone, from primitive to scientific technique of the latest type. The youth from the remotest high schools are no longer remote from the industrial centers or from the institutions of higher learning; they are keenly aware, by reason of observation and contact, of what is going on, and they are definitely reaching out to grasp the opportunities offered, with relation to Kingsport, Chattanooga, Ducktown, Oak Ridge, Alcoa, Old Hickory, T.V.A., all of which industrially significant centers, not to mention smaller ones dotting the State, involve a need for the knowledge of physics.

So we dismiss the insinuation that physics is not related to life in Tennessee, and boldly assert that it is very closely involved with life; which is a somewhat staggering prospect when we consider the feeble effort being put forth in the field of education to effect a liaison between intelligent understanding of the physics fields and the actual application of them in industry.

How closely does consciousness of the physics field impinge upon the mind of the "common man?" The writer has often taken opportunity to explain what physics is about to the uneducated practical men—the plumber, logger, bricklayer, machinist. Never has he failed to elicit from these men amazement that the schools taught these things. Recently he was asked by a purely mountain-bred man for information about how to get books on air-conditioning and refrigeration. Examining a local bookstore operated by a dealer who specializes in supplying popular demand, the writer found a very creditable array of books of every type of physics subject; these books were in answer to a demand reminding one of the demand for the

manuals popular in the early nineteenth century by a people awaking to the possibilities of simple mechanics.

One duty of physics education, is then, to teach the youth where physics touches his life, *or* where life touches his physics. To some extent the student in his own consciousness is concerned already, through radio, cinema, aeronautics, gadgets at home, and hobbies such as photography and radio, with physics. The life interest is there, and often as not, has a vocational trend. We stress vocational guidance in programs that reach as low as the sixth grade, on up through high school. Physics deals with the *foundations* of many vocations, and touches vitally many others. It is folly to ignore that a good physics course is very vital in integrating the knowledge and understandings underlying many fields of the youth's life dreams and ambitions. Even the boy on the farm is concerned with electrification; he handles machinery and engines and mechanized tilling implements. The technique of presentation is not to be differentiated into two opposing aspects with relation to life, one bringing life to physics, and the other bringing physics to life.

At the age of seventeen we find the youth much concerned with evaluating life and quick to seize opportunities that give meaning to his life. It is an axiom of educational method that we must credit his mind with validity; and, wherein we fail to do so, we find roots of many educational difficulties. The place his physics holds for him, as a physical being adjusting himself to a very real physical world, cannot be sanely brushed aside. Spiritual and personality values as well as sane physical adjustments are granted nowadays as resulting from participation in athletic and physical education; likewise valid and vital, is the matter of adjusting the youth to a physical world and universe by understanding it, and this, by the same token, possesses spiritual and personality values. It cannot be denied that a sane self-consciousness is to be enhanced and strengthened by an intelligent understanding of the principles by which man has learned to use and control the physical energies of the universe; physics concepts reach to the stars, and dignify the mind of man.

What value has physics from the purely cultural and liberal arts standpoint? Let us quote Ulich[1] in *Fundamentals of Democratic Education:*

"Now we all acknowledge the existence of something common in human nature that older psychologists, afraid of this often misused term, call

[1] Ulich, Robert, *Fundamentals of Democratic Education*, American Book Company, p. 31. 1940.

"vital or motivational, urges," "drives," "needs," or "propensities." These qualities . . . seem to work in the common groundwork of the human being the moment he feels himself exposed to a certain challenge from the outside, or even before."

In another connection, Ulich refers to the capacity of man to devote himself to pursuits that "transcend himself." There is much in physics of an abstract nature that calls into play many of these undefined capacities, and furnishes an outlet for them. It not only touches life on the levels of sensory experience, but it is also concerned in a magnificant role of furnishing the mind of man an outlet for the drive to transcend himself, by supplying him with tools for such accomplishments as projecting his voice through space by media that soundlessly convey noise with the speed of light. Such phenomena fascinate the adolescent mind, which seeks self-realization by welcoming opportunity for finding itself by transcending itself in breaking down limitations of ordinary experience. No one is more conscious of this than the physics teacher who observes the minds and reactions of his students. It is due to this capacity and drive that mankind has built up the field of physics to account for the energies of nature beyond himself. Thus physics is inherently part of man. It has given him the strongest impelling drive, very recently, to achieve compatibility along lines of world social adjustment by the discovery and use of sub-atomic energy; physics has definitely revolutionized world social and political foundations, and we now wonder in breathless stupefaction and awe.

As in no former period of history, physics is a life demand. Education must rise to the occasion. The time for quibbling over ancient questions of whether physics is to be related to life, or life to physics, as opposed aspects, is now past. Teaching technique will utilize both aspects of approach, calling from past experience and present experience to build principles, and will apply principles to new life experiences, and will be directed toward life in the future.

Unlike the human beach-comber of fiction, who is almost always a dirty, idle, shiftless loafer, the beach-combing birds of sandpiper-snipe-godwit group are models of neatness and diligence. They probe for aquatic dainties with their long beaks, but they also turn their attention to things which the land provides, and which we human dwellers on the land are only too glad to be rid of. Ornithologists studying their fare have found it to include such pests as grasshoppers, army worms, cutworms, boll weevils, fever ticks, horseflies and mosquitoes.

ELEMENTARY SCIENCE

WATER—A FIRST GRADE UNIT[1]

MYRLE DAY, MARGE HOFFMAN, GLADYS SMITH

Elementary Science Curriculum Committee, Hammond, Indiana

INTRODUCTION TO UNIT

Children everywhere and of all ages have experiences with water. We want them to know the importance of water, first in the home and then in the growth of plants and animals. We also want them to realize their experiences in order that they may have a known foundation for other facts.

It is not compulsory to introduce the study of this unit in the order used here. The starting point may be a rainy day, a snow storm, an excursion or discussion about the wonder and beauty of water.

We have tried to develop the following basic ideas.

I. We use water for cleanliness.
II. Cleanliness is beautiful.
III. We use water for drinking.
IV. Water is in the air.
V. Water comes from the air.
VI. Water is not alive.
VII. Animals and plants depend on water.
VIII. There are many forms of water.

MATERIALS FOR TEACHING UNIT

sponge	bulbs	siphon (rubber tube)	soap—bubble pipes
grass seed	cactus	bottles	teakettle
cotton	terrarium	bird bath	small magnifying glass
carrot	pans	dish pan	flower pots
aquarium	hot plate	material for boats	funnel

BOOKS FOR USE IN TEACHING THIS UNIT

Blough, Glenn O. and Parker, Bertha: *Water Appears and Disappears.* Row, Peterson & Co., Evanston, Ill.

Dolman, Helen et al: *We see, Sunshine and Rain, Through the Year,* L. W. Singer and Co., Syracuse, N. Y.

Craig, Gerald: *We Want to Know, We Find Out.* Ginn & Co., Statler Building, Boston, Mass.

Beauchamp, W. et al: *Look and See.* Scott, Foresman and Co., Chicago, Ill.

Wyler, R. and Hughes, A. *Experiment Book* (Picture Scripts).

Manuals for all the above.

[1] See SCHOOL SCIENCE AND MATHEMATICS, Vol. XLVI, No. 5, May 1946, pp. 433–437 for the *Purpose Basic Objectives,* and *The Organization of Materials of Instruction in Elementary Science* by the same authors.

I. Where do we find water?

Things to Do	*Understandings*	*Teacher's Bibliography*	*Enriching Activities*
Discussion. Discuss where children have seen water on the way to school and on trips taken.		Water Appears and Disappears, p. 25.	Collect pictures showing where we find water. These may be used for bulletin boards, scrap books, and charts.
Field Trips. Take a walk any place near the building where water is found. Dig down and find moist dirt. Look under leaves, bricks and boards to find moisture.	Water is on the ground.	Singer Manual. Field Trips, pp. 15–18.	Songs. Songs for Nursery School by Laura Pendleton MacCartency. Little Pool, p. 52. Raining on the Town, p. 59. Puddles, p. 60. It's Raining, p. 60.
Take a walk following a rain or a snow. Watch rain as it hits the ground.	Water is in the ground.		Sing a Song—World of Music Series by Ginn & Co. On a Rainy Day, p. 21. Rain, p. 32. My Rubber Coat, p. 47.
Children read and get facts from pictures. We Want to Know, pp. 79–91. We See, pp. 14–15. Sunshine and Rain, pp. 4–7; 55. Look and See, pp. 40–41.	Water is in the ocean, rivers, brooks and lakes.	Craig Manual, pp. 15–17. Reading procedure Manual that accompany these books.	Listen and Sing. On a Rainy Day, p. 72. Song for a Rainy Day, p. 94.
Read the story "Rubbers and Rain" in *Sally Does It*, p. 66.			Poems. Silver Umbrella. Little Rain, p. 148. April Rain Song, p. 147. A Shower, p. 147. Umbrella Brigade, p. 148. Poetry Book I.

II. How do we use water?

Things to Do	*Understandings*	*Teacher's Bibliography*	*Enriching Activities*
Have daily health inspection.			
Experiments.			
1. Call attention to children's hands and faces before and after washing. Some try washing in water from bathroom, others in rainwater caught in pans. Note the difference in the soapsuds.	Water keeps us clean.	Craig Manual, "Interpreting Environment Through Science," "Meanings Through a Variety of Activities." Pp. 8–11.	Make scrap books on uses of water
2. Have a child wash dirty doll-dress, dirty cups, vegetables, etc. Note the difference in the clean article. Let this water stand and see the dirt that settles.	Water keeps everything clean.		
Discussion.			
Stress importance of drinking water regularly, how much to drink, when to drink it.	We drink water.		Make posters or drawings telling how many glasses of water children should drink each day.
Experiments.			
1. Demonstrate with dehydrated milk, bouillon cubes, jello, lemonade, etc., the water content of food.	Water is a part of many foods.		
2. Dry apple slices and see the difference after water is gone.			
3. Pour water on the hand and feel it as it comes from faucet, pump or hose and note the force or power.	Water has power.		Make a paddle wheel as suggested in *We Find Out*, pp. 107–113.
Children read and study pictures. We Want to Know, pp. 92–95. We Find Out, p. 33. Through the Year, pp. 46–47.		Manuals that accompany these books—for these pages.	
Read to children the story of "Mary Ann's Drink" from *Sally Does It*, p. 10.			

III. How do animals use water?

Things to Do	*Understandings*	*Teacher's Bibliography*	*Enriching Activities*
Trips.			
Make excursion to observe animals in the home, birds and animals in the park, animals on the farm.	Animals need water in order to live.	Craig's Manual, Water, pp. 34–35.	Songs. Songs for Nursery School. The Alligator. The Goldfish. Run Little Crab.
Observations.			
Care for rabbits, chickens, a canary or other animals and observe their use of water.	Animals drink water.		Progressive Music Series Book I The Song Sparrows Toilet, p. 19.
Make and care for a bird bath.			
Make an aquarium or vivarium.	Some animals live in water.	Singer Manual, pp. 21–22.	Listen and Sing. Little Duckie Duddle, p. 13.
			Poems. There was a Little Turtle. Down in the Meadow.
Children read and study pictures. We Find Out, pp. 12–13; 21; 43–53; 60–68; 204–209. We Want to Know, pp. 96–98. Sunshine and Rain, pp. 54–59. Through the Year, pp. 18–23; 112–121. Look and Learn, pp. 16–17.		Manual to accompany pages in these books.	I Like Animals, by D. Baruch. Yellow Canary. Frog. Goldfish. Turtle. The Elephant.

IV. How do plants use water?

Things to Do	*Understandings*	*Teacher's Bibliography*	*Enriching Activities*
Experiments.			
1. Have two plants; water one and not the other. Note difference and that one not watered withers and dies.	Plants must have water to grow.	Science for Elementary School by Craig. Title of article, "Some Plants Store Water	Songs "Your Garden," in *Songs for Little Children* by Gaynor.

2. Dig down into the ground and find moist dirt at roots of plants. Measure depth—Pour water on ground and later measure depth again.	Plants get water from the rain in two ways. Through their leaves and through their roots.	and Waste Products in Their Stems," pp. 346–347.	
3. Plant bird or grass seed on a sponge. Water each day.			
4. Plant seeds on cotton to show roots and leaves.			
5. See how plants get their water by putting cut carrot in colored water as shown in Experiment Book, p. 6.		Singer Manual. How to Make a Terrarium, pp. 18–20.	
6. Have plants in water in an aquarium.	Some plants live in water.		
7. Plant a bulb in water.		Craig Manual. Use of Visual Aids, pp. 13–14.	
8. Have a cactus in room to show how little water it needs.	Some plants use very little water. Too much water washes out some plants.	Experiment Book, p. 6.	
9. Make a terrarium as outlined, p. 18 *Teachers Manual*—Singer.			
Children read these books and study pictures. We Want to Know, pp. 96–99. We Find Out, pp. 13–14; 52–53. We See, pp. 10; 31. Through the Year, pp. 132–137. Look and Learn, pp. 21; 57–59.		Manuals to accompany these pages.	

V. What happens to water?

Things to Do	*Understandings*	*Teacher's Bibliography*	*Enriching Activities*
Excursion.			
Go outside following a rain and watch water soak into the ground.	Water sinks into the ground.	Science for the Elementary School Teacher, by Craig, p. 260.	

Experiments. Pour water on loose dirt and see where it goes. Make hills and valleys in a sand pile. Make an impression in each. Fill impressions with water. Make an opening in lower impression and note that water does not run out. Do likewise in higher impression and note that water runs to lower one.	Water flows from a higher to a lower level.		Make riddles about what happens to water, ice, and snow.
Discuss. Discuss how in some way water finally gets into the ocean—through brooks, rivers, ponds and lakes. Mention the fact that this area was once covered by Lake Michigan. Visit as many kinds of above mentioned bodies of water as possible.		Craig Manual, The Siphon, p. 45.	Siphon water as suggested in We Find Out, pp. 94–100.
Children read and study pictures. We Want to Know, pp. 79–91. We See, pp. 14–15. Sunshine and Rain, pp. 52–55. Through the Year, p. 18. Look and Learn, pp. 15–17.		Manuals to accompany these books.	Collect pictures of different kinds of bodies of water.
Notice entrance holes to sewers. Are sewers lower than the streets? What happens if sewer entrance is closed? When water is snow it is hauled away.	Water runs into the sewer.		
Experiments. Do all the experiments on evaporation suggested in: Water Appears and Disappears, pp. 11–13. Through the Year, pp. 48–53. We Find Out, p. 152.	Water evaporates. Wind and heat help water to evaporate.	Water Appears and Disappears, pp. 6–12.	Songs. Progressive Music Series Book I. Snow, p. 86. Listen and Sing. Snowflakes, p. 92.
Children read. We Find Out, pp. 143–151.	Water in the air is called water vapor.	Science For the Elementary School Year, by Craig, pp. 212–222.	Poems. Hammond A.C.E. Folder, 1943. Snowflakes.

Examine snow flakes. Take a walk in the snow. Take in snow and melt it. Put the melted snow outside and see what happens.

Bring in icicles and melt.

Note the difference in the quantity of both snow and ice when melted. Let melted snow and ice settle and see the dirt.

Make a snow man and watch him melt day by day.

Put water in a glass bottle. Leave outside (if freezing weather) and see what happens.

Children read and study pictures.
- We Want to Know, pp. 100–107.
- We Find Out, pp. 133–142.
- We See, pp. 30–33.
- Through the Year, pp. 74–78.
- Look and Learn, pp. 42–45.

VI. How do we enjoy water?

Things To Do

Blow soap bubbles.

Make lemonade for a party.

Sail boats in a large tub, sandbox, in a water puddle.

Skate or slide on ice.

Play in the snow.

Children recall experiences they have had coasting, swimming, wading, fishing, riding in boats, and making mud pies.

Compare type of clothing we wear when it rains or snows

Children study.
- We Find Out, pp. 111–112.
- We See, pp. 14–15; 22–23.
- Sunshine and Rain, pp. 4–7; 32–33; 52–53.
- Look and Learn, p. 52.

Water freezes into snow or ice.

Melting is a change from a solid to a liquid.

Freezing is changing from a liquid to a solid.

Understandings

Water is fun.

Teacher's Bibliography

Singer Manual, p. 73.

Manual to accompany these pages.

Enriching Activities

Songs.

Progressive Music Series Book I.
- Soap Bubbles, p. 97.
- Blowing Bubbles, p. 52.
- Coasting, p. 74.
- Skating Song, p. 98.
- Mud Pies.

Listen and Sing.
- The Skates, p. 67.

Poems.

Hammond Choral Speaking, 1939.
- Who Likes the Rain?

My Ship, by Stevenson.
- The Silly Snowman.

Sung Under the Silver Umbrella.
- Ice, p. 159.
- Snow Toward Evening, p. 161.
- White Fields, p. 160.
- Winter Rune, p. 161.

Cut out pictures of snowflakes.

Make a frieze showing where water goes or our world in winter.

Teacher show her collection of pictures of beauty in water and encourage children to find similar pictures.

Discuss trips taken when they saw beauty of foam, waterfalls, sunset or sunrise over water.

Observe the beauty of nature after a rain storm, the rainbow, the "cleanness" of growing things. Look at snowflakes through magnifying glass.

Discuss or listen to sounds of rain falling, swish of the lake, trickle of a brook, the songs of birds following a rain.

Water is beautiful.

Make a big book of stories about fun in the rain or snow and illustrate it.

Make a scrap book of magazine pictures and cards showing beauty of water in all forms.

Make a rainbow with a spray of water or a glass bowl.

Write original poems.

Children read.
We Want to Know, pp. 122–123.
We See, p. 19.
Sunshine and Rain, pp. 30–31.
Through the Year, pp. 72–73; 78.
Look and Learn, pp. 41–44.

Emphasize the fact that God made everything and that all things are interdependent.

Note the beauty and quietness during and after a snow storm and feel the Power behind it.

Water is wonderful.

Teacher read.
"God Gives Us Water" in *Tell Me About God*, p. 32.

Psalm 95: 3–5

"3. For the Lord is a great God, and a great King above all gods.

"4. In His hand are all the deep places of the earth: the strength of the hills is His also.

"5. The sea is His, and He made it: and His hands formed the dry land."

Psalm 33: 5

"the earth is full of the goodness of the Lord."

Job 5: 10

"God giveth rain upon the earth, and sendeth waters upon the fields."

TEACHING FUNCTIONAL THINKING IN MATHEMATICS

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About six years ago we presented a paper at the Meeting of the National Council of the Teachers of Mathematics in connection with the Annual Meeting of The American Association for the Advancement of Science at Columbus, Ohio, in which an attempt was made to analyze functional thinking in terms of six propositions. Subsequent experimentation and observation with students in our mathematics classes have confirmed our conclusion that the set of six propositions do adequately interpret functional thinking. We shall draw upon the theme of that paper, which was published in The Mathematics Teacher for January 1941, to further elucidate functional thinking in mathematics, and to emphasize this type of thinking as a definite learning product of mathematical instruction.

From times immemorial many volumes have been written on the importance of developing the art of thinking. In general, we have accepted the truth of the proposition that while the art of thinking may not be essential to living, it is extremely essential to human living. Perhaps, that distinguishing characteristic of thinking might be used as a criterion to evaluate the efficiency of our educational systems and institutions in developing the inherent abilities of the individual to think. If the art of thinking characterizes the life of the individual, or of the society, then it must be granted that the development of thinking should be a primary objective of our educational system.

For the past thirty years in this country many papers have been presented at meetings of the teachers of mathematics, and many articles have been published in mathematical journals, and many a textbook has been revised, at least in its preface, on the significance of functional thinking. From the vast amount of information on this subject before us we are justified in formulating the proposition that while functional thinking is not essential to human living, it is extremely essential to living in a world based upon scientific discoveries and inventions. This distinguishing characteristic of functional thinking might be used as a criterion to evaluate the efficency of our mathematical instruction in developing the thinking powers of the individual to think functionally. Again, if the art of functional thinking

characterizes the scientific thinking of the individual, then it must be granted that the development of functional thinking. should be a primary objective of our mathematical instruction

We may analyze functional thinking in terms of the following six propositions, which state abstractly the intrinsic characteristics of functionality in its relations to the art of thinking. The symbols used have the following meanings. An entity is represented by the symbol x. A class of entities $x_i(i=1, 2, 3, \cdots, n)$ is represented by C_x. A property possessed by an entity x or by a class C_x is represented by P. Finally, a relationship existing between two or more entities or between two or more classes is represented by R.

The first proposition states that x *has property* P. This proposition defines the entity x in terms of the property P. It does not define the property P. The property P may be defined in terms of another property P'. In this case P plays the role of the entity x. This proposition implies the recognition and formulation of the property P, and it also implies the identification and classification of the entity x. For example, the statement "the function $x+2$ is a linear function" implies that the function $x+2$ is identified and classified in terms of the property of some functions being linear.

The second proposition states that *entities* $x_i(i=1, 2, 3, \cdots, k)$ *have property* P. This proposition implies that some x's have the property P, and that these x's form a sub-class C_x of the class C in terms of the classifying property P. This proposition plays an important role in induction.

The third proposition states that the *class* C_x *has property* P. The proposition implies that the x's that have the property P constitute a class C_x, and that every member of the class C_x has the stated property. While Proposition 2 implies the recognition of the property P and the identification of x_i, having this property, Proposition 3 implies that the x's constitute a class with respect to the property.

Functional thinking is concerned in recognition, rationalization, and manipulation of relationships between quantities. The related quantities are not two isolated entities, but each quantity constitutes a set or class of values. Before the desired relationship between the related quantities can be determined, the set of values of each quantity must be definitely determined. Propositions 1, 2, and 3 undertake to study the relationship between the elements of a given class in terms of the class property.

The fourth proposition states that x *has relation* R *to* y. That is, an x belonging to the class C_x and a y belonging to the class C_y are associated with each other according to the relation R. This proposition implies the identification of x and y as belonging to their respective classes, the understanding of the nature of the relation R, and the association of x and y with respect to the stated relation. For example, the statement, "the number pair (x_1, y_1) defines the point $P(x_1, y_1)$," implies: (1) that x_1 is an element of the ordered class C_x of real numbers, ordered on a horizontal axis; (2) that y_1 is an element of the ordered class C_y of real numbers, ordered on a vertical axis; (3) that point P is the intersection of two lines respectively parallel to the x-axis and the y-axis; and (4) that of the two intersecting lines one passes through the point $x=x_1$ on the x-axis and the other passes through the point $y=y_1$ on the y-axis.

The fifth proposition states that $x_i(i=1, 2, 3, \cdots, k)$ *has relation* R *to* y_j $(j=1, 2, 3, \cdots, 1)$. This is a generalization of Proposition 4. It implies that the x's belonging to the class C_x and the y's belonging to the class C_y are associated according to the relation R. The correspondence is from x_i to y_j, but not necessarily in a biunique fashion. That is, two or more x's may be related to the same y.

When the correspondence between the x's and the y's is exhibited tabularly we have the tabular study of functionality, which is the first step in the determination of a functional relation between the set C_x and the set C_y. When the associated number pairs (x_i, y_j) are plotted on a selected pair of axes we have the discrete point-graph of the relationship.

The sixth and last proposition states that *class* C_x *has relation* R *to class* C_y. This proposition compares two classes C_x and C_y by establishing a correspondence between their elements. This is a generalization of the relation stated in Proposition 5. The results of experimentation and observation stated in Proposition 5 are formulated into a general law or function displaying analytically the relationship between the set of values x and the set of values y. It is the final step in curve fitting or the determination of emperical formulas. When the function is stated, the relationship holds not only for the specific values x_i and y_j of Proposition 5 but also for other values in the sets C_x and C_y. Proposition 6 implies that the stated relation R may be used for interpolation and in some cases for prediction. The graph constructed on integral or rational values becomes a continuous

graph valid for all the real values of the related sets.

These six propositions, though stated abstractly, are manifested whenever and wherever thinking in terms of quantitative aspects of the world about us takes place. Functional thinking is the recognition, rationalization, and manipulation of the quantitative properties of a set of entities and of the relationship between that set of entities and another set of entities. Without some degree of functional thinking in the ordinary affairs of life, there is nothing in the mental process which merits the name thinking. In the strictest sense, to think at all means to think functionally.

Functional thinking in mathematics is a prototype of excellence or standard for similar thinking in other fields of thought. The entities of mathematics, such as number and geometric form, in terms of which functional thinking is done, are readily discernible, their properties are precisely stated, and the relationships between them, when stated mathematically, are exact, their nature comprehensible, and their implications predictable. Consequently, mathematical instruction should be the chief laboratory where functional thinking is developed. That is, functional thinking should be the primary objective of all mathematical instruction, beginning at the grades, continuing through the high school and the college.

The learning process, whatever its nature, should be identified and evaluated on the basis of learning products. In mathematics we distinguish four types of learning products. They are recognitions, rationalizations or understandings, manipulations, and appreciations. With the latter type of learning our class room instruction is not primarily interested. The other three types should be considered whenever we attempt to evaluate instruction. These types of instruction, though distinct, overlap in the learning of a process or concept of mathematics. For example, one may recognize the fact that the slope of the straight line $y=mx+b$ is m, without being able to demonstrate the validity of the fact. One may understand the fact that a fourth degree equation in x has four roots, real or complex, without being able to solve the equation to determine the roots. One may also manipulate the rule for finding dy/dx for a large number of functions without understanding what the derived function represents.

The simplest type of learning is recognition. Thus in Proposition 1 one may recognize x as belonging to a certain class C_x, or

in Proposition 4 one may recognize the relation between an entity x and an entity y, without being able to rationalize the relationship. A great deal of learning, both in mathematics and elsewhere, is of recognition-type.

In its simplest form understanding is manifested whenever a concept or process is rationalized. In general, understanding is associated on the one hand with recognitions and on the other hand with manipulations. Thus, by recognition the entity x is identified as belonging to the class C_x by means of the class property P. By rationalization, the existence of the entity x is justified, its inclusion in the class C_x is established, and the nature of the class property P is explained. Symbolically, we may represent the idea as $C^P \cdot x^P \cdot \cdot \cdot C_x$, which means that there exists a class C which contains all the elements possessing the class property P, and that there exists an entity x possessing the property P, and hence the implication is that x is an element of the class C.

One type of rationalization is concerned with the properties of entities x_i. It proceeds by induction on x_i having the common property P and establishes the existence of the class C_x. It may also proceed by postulation of the existence of the class C_x in terms of the property P, and demonstrate by deduction that x has the property since it is an element of the class.

Another type of rationalization deals with relationships between two or more entities belonging to the same class or to different classes. While recognition identifies the relationship R, rationalization establishes the existence of the relationship by considering the causes which produce it. Rationalization of the single statement xRy may be a logical consequence of the three statements, CRc', C_x, and C_y. That is, if every element of the class C is associated with a corresponding element of the class C', and if the element x is in the class C and the element y is in the class C', it follows that x is associated with y according to the relationship R.

Rationalization may also proceed by induction on the separate statements X_iRy_j to establish the existence of the general statement C_xRC_y.

The third type of learning consists of the development of certain abilities and the acquisition of specialized skills. Manipulation may or may not be associated with recognitions or rationalizations. That is, one may learn to apply a process and in its application may acquire certain manipulative skills without

understanding the process or be able to explain why it is done in that particular way. One learns to use a certain rule and becomes quite efficient in its use without knowing what the rule implies. Using the tables of logarithms is an example of such learning.

Having analyzed the propositions which are basic in functional thinking, and their acquisition as type learnings, we are now in a position to undertake the study of how this type of thinking may be actually acquired in mathematics classes, and how the teaching of mathematics should be concerned in making functional thinking a primary objective of instruction. To the teacher of mathematics who is concerned with teaching, and developing functional thinking, every page of the textbook he may be using is filled with examples and exercises in functional thinking, whether the term function is used or not. We shall attempt to give instances in various courses, both in the elementary school and the high school, where functional thinking can be developed.

The three types of learnings in mathematics are products of processes and concepts which constitute the particular course or subject of study. Let us consider the process of addition, which we start in the early grades and continue through arithmetic, algebra, geometry, and advanced courses in college mathematics. Can we teach functionality and functional thinking in connection with addition? We can and we should.

We teach the 100 addition combinations in a certain sequence which is supposed to have been discovered by expert psychologists, who are certainly not interested in teaching functional thinking, or even any thinking, at that level, on the basis of difficulty in learning the combinations. We teach 200 assorted facts, without even an attempt to show that they are related. We have all kinds of elaborate schemes, such as flash cards, to assist us in this learning by rote. Then when we offer the child his first opportunity to use one of these combinations in a simple problem, we are shocked to discover that the child can not think at all. Why should he? We did not teach him to think when he was learning his combinations, All we did was to flash cards at him, and all that he was expected to do was to flash the answer back at us.

Now suppose we be sensible, mathematically sensible, about the matter. What is the first method of studying functionality? The tabular method. Why not use a table to teach the combina-

tions? It is certainly as easy as the flash cards, and it has the added advantage that the child has an opportunity to do a little bit of thinking. Take the first row of the table. We have the 10 figures 0, 1, 2, $\cdots$, 9. In each of the other rows we have an example of functionality, namely, $1+n$, $2+n$, $\cdots$, $9+n$.

TABLE I

	0	1	2	3	4	5	6	7	8	9
0	0	1	2	3	4	5	6	7	8	9
1	1	2	3	4	5	6	7	8	9	10
2	2	3	4	5	6	7	8	9	10	11
3	3	4	5	6	7	8	9	10	11	12
4	4	5	6	7	8	9	10	11	12	13
5	5	6	7	8	9	10	11	12	13	14
6	6	7	8	9	10	11	12	13	14	15
7	7	8	9	10	11	12	13	14	15	16
8	8	9	10	11	12	13	14	15	16	17
9	9	10	11	12	13	14	15	16	17	18

Now suppose we consider any diagonal of the table, say the diagonal consisting of the number 10. Here we have an example of the function $m+n=10$. Furthermore, we discover the fact that $m+n=n+m$. The table is filled with manifestations of functionality, if we will only look for it.

Then too, if we seek visual aids to learning, why not use the second method of studying functionality, namely, the graph. We can construct a simple nomogram based upon the table, which is more compact than the two hundred flash cards, one for each addition fact. A little actual classroom experiment will demonstrate that the nomogram can be read easily, and certainly with more motivation than a flash card. The complete nomogram could be constructed separately at first, one for each diagonal number, as shown below for the diagonal number 10. Then, after the combinations have been mastered, the complete nomogram chart can be hung on the wall of the classroom, and the children should be encouraged to use it.

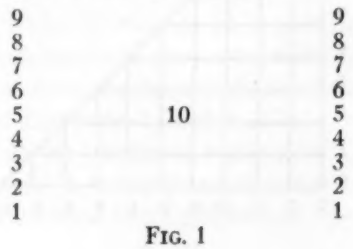

FIG. 1

The complete nomogram, corresponding to the table, is given in Figure 2. The children could easily construct nomograms both for their own individual uses and for the classroom use.

9	18	9
	17	
8	16	8
	15	
7	14	7
	13	
6	12	6
	11	
5	10	5
	9	
4	8	4
	7	
3	6	3
	5	
2	4	2
	3	
1	2	1
	1	
0	0	0

FIG. 2

While opinions differ as to when we should actually begin the reading of charts, it is reasonable to assume that if we teach the reading of pictures in the primary grades, then we can certainly teach the reading of simple graphs. The pedogogic experiment is worth trying. We can construct a simple graph based upon the combinations of the table. The vertical and horizontal lines should be drawn to assist in reading the number pairs, as shown in Figure 3. Figure 3 is based upon the relation $m+n=10$. Similar charts can be constructed for the other diagonal numbers of the table.

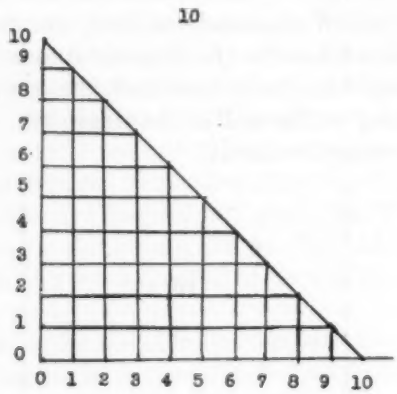

FIG. 3

While separate tables and charts may be constructed for the subtraction combinations and facts, the addition table and the addition nomograms and graphs can be used to teach the subtraction combinations. A little practice will show the child how to read the particular combinations.

The multiplication table based upon the 100 multiplication combinations may be used to teach functional thinking in the same way that the addition table is used. The various rows of the table exhibit the functional relations n, $2n$, $3n$, $\cdots$, $9n$, for $n=1, 2, 3, \cdots, 9$.

If the teacher desires to construct nomograms based upon the multiplication table, he can reduce the function $xy=z$ to $\log x + \log y = \log z$, and then construct an addition nomogram using logarithmic scales. As far as the reading of the nomogram is concerned, the child should not encounter any difficulty at all.

Graphs may also be constructed for the various rows of the multiplication table. Each of the linear graphs is of the form $y=ax$, for $a=1, 2, 3, \cdots$.

Some teachers may object to this proposal on the grounds that it is too difficult. Well, the development of functional thinking is difficult too. The proposition for discussion is: are we sincere in our claims that mathematics courses are the best means of training for functional thinking? If we are, then we can at least experiment with the proposal in our classes. Of one thing we can be sure, when we teach the child to think functionally, his interest in mathematics will increase, and the mathematical facts that he learns he will learn for keeps.

What about fractions? Can we teach functionality in connection with fractions? At the early stages of the work with fractions we teach the meaning of a fraction, such as 2/3, as indicating a certain portion of a whole quantity, the latter being represented by unity. Later on we interpret a fraction as a rational number, that is, as the ratio of two integers. In both cases we can associate with a fraction the concept of functionality.

Let us first consider a fraction as a portion of the whole or unity. The most fundamental property of the fractions is the law that the fractional form an/bn equals the fractional value a/b. Thus, the class of fractions 1/2, 2/4, 3/6, $\cdots$ infinitely many in number, all have the fractional value 1/2. Recognition of this important fact is but a recognition of functional relationships. If this property is stressed and emphasized, operations with frac-

tions, especially addition of fractions, ought not to be so meaningless that, instead of creating interest in arithmetic, they produce a dislike for mathematics that it is not easy to overcome even in the high school and college.

If we look at it understandingly and not merely follow the text, we see that in reality adding two fractions is the same thing as adding two denominate numbers. Thousands of years ago the Egyptians recognized this fact and reduced the arithmetic of fractions to that of unit fractions. The unit fraction is the solution of our difficulty. If the child can add 3 dimes and 4 dimes, then he can add 3(1/10) and 4(1/10). The idea in adding denominate numbers is that they are expressed in the same unit. Let us call the unit U. Then, $mU+nU$ becomes $(m+n)U$. The unit U may be a dollar, a pint, a foot, or a unit fraction. Let us see how this idea actually works. Suppose we are adding 2/3 to 3/8. By the fundamental property of fractions $2/3=4/6=\cdots=16/24$ or 16(1/24), and $3/8=6/16=9/24$ or 9(1/24). Thus 2/3+3/8 becomes 16(1/24)+9(1/24) or 25(1/24).

Can we apply the same idea to the rationalization of the product of two fractions? Why not? If we can multiply two units U_1 and U_2 and interpret their product as the derived unit U_1U_2, then we can use the idea in the product of two fractions. We do multiply 5 feet and 3 feet and call the product 15 square feet. Similarly, we can multiply 5/8 by 3/8 and call the product 15(1/64) or 15/64. If we can multiply 5 feet by 3 pounds and call the product 15 foot-pounds, then we can multiply 5/8 by 3/7 and call the product 15(1/8·1/7), or 15(1/56), or 15/56. Some will say that it is much easier to multiply the numerators together and the denominators together. Yes, it is easy that way. But that way the child learns to do it by rote, without understanding. Here we are concerned with teaching the child to think and not to become an expert performer of tricks. That he even forgets how to perform the tricks, under our present mode of teaching, is evidenced by the fact that in the high school and even in the college we find students, graduates of eight years of instruction in arithmetic, adding 1/3 to 2/5 and getting 3/8. The partial learning by rote in multiplying fractions carries over to similar partial learning in adding fractions.

Before leaving fractions, we should call the attention of the teachers of arithmetic that if they interpret a fraction as a ratio and do actually teach the concept of ratio and proportion and fail to teach functional thinking, then there is something radically wrong with our teaching. For, the ratio $y/x=k$ is but the

linear function $y=kx$, and the proportion $y_1/x_1=y_2/x_2$ is the equality of the corresponding values of y and x. Formal teaching of functionality may well be undertaken with the study of ratio. The dependence of variable quantities and the type of variation are easily demonstrated for the function $y=kx$.

In the arithmetic of the seventh and eighth grades a great deal of mensurational work is done informally and intuitively with lengths, areas, and volumes. The formulas for such measurements are but analytical statements of functions, and the emphasis should be placed upon analysis of problems as special cases of the functions involved.

The use of the formula in the solution of problems should be undertaken as early as possible, not only in the problems based on mensuration, but also in problems based on business relations, on motion, rates, work, and other types. A problem may be classified as a one-situation problem, a two-situations problem, or as a many-situations problem. In a one-situation problem direct substitution in the characteristic formula yields an evaluation or a solution of an equation. For example, if the base and the altitude of a triangle are given, direct substitution in the formula and the performance of the arithmetic calculations yields the answer, while if one dimension and the area are given, a simple equation must be solved to obtain the answer. In a two-situations problem, the characteristic formulas must be recognized and the stated values must be substituted in each formula. The solution may involve one or two equations, depending on the particular method or device used. In a two-situations problem we may find two special situations of the same formula. Most of the motion problems are of this latter type, being based on the formula $d=rt$.

Even though in this discussion we are not concerned with the technique of problem solving, we are, nevertheless, interested to determine whether or not the solution of problems offers an opportunity for the development of functional thinking. Experience has shown to us that the use of analysis is the most efficient method of solving any problem. The analysis of a problem involves: (1) recognition of the characteristic formula or relationship; (2) identification of the explicitly stated values of the variables, or implied values; (3) the determination of the unknown quantity; (4) the performance of the involved operations either in the evaluation or the solution of the equation or equations; and (5) checking the answer.

Such an analysis presents excellent opportunities for the

teaching and the development of functional thinking. The first step requires an understanding of the common formulas upon which most of the problems of the seventh and eighth grade arithmetic are based. It is too much to require of a pupil to recognize a formula that he does not understand. Thus, if we expect to teach solution of problems by analysis, we must first teach formulas, and a formula is a statement of functionality.

The identification of the stated or implied values of the quantities in the problem, again, demands an understanding that the quantities represented by the letters of the formula are variable quantities, having different values in different situations. Rationalization of the concept of variation is the essence of functionality.

In steps 3 and 4, we are again determining a special value of a variable quantity. Step 5 may also be used to develop functional thinking if we resort to the scheme of dimensionality. That is, each quantity in the formula of the problem has a stated value or a value determined by step 4 which is a denominate number, or an abstract number. If the values are denominate numbers, then each is expressed in terms of a certain unit. When the values of the variables of the formula are substituted in the formula, the two sides of the equation must reduce to the same unit or to an abstract number. If emphasis is placed upon this idea of checking the dimensionality of the formula, the answer of the problem will be expressed correctly in terms of the unit involved. In fact the recognition of the units involved may be considered as important as finding the answer.

We have pointed out specifically how the teaching of arithmetic may develop functional thinking. Of necessity, our suggestions have been of a general nature, and we have not given the details in each instance. Such details are easily supplied by the teacher of arithmetic who is earnest in his efforts to train the child in the art of functional thinking. The opportunity is there, present in every process and concept of arithmetic. That few of us have taken advantage of this opportunity, is not a condemnation of arithmetic but of our methods of teaching and our educational philosophy.

When we consider the situation in the high school, frankly we have reason to become discouraged. Inspite of the fact that recommendations were made as far back as thirty years ago to make the teaching of the function concept the primary educational objective of our mathematics classes in the high school,

we continue presenting the same list of unrelated topics in algebra and the same sequence of propositions in geometry. Inspite of the fact that many articles have been published in mathematical journals showing how the concept of function may be taught in algebra and geometry, we have continued and persisted in teaching both subjects to develop manipulative skills. It has been demonstrated time and time again that when we teach functionality we actually develop the necessary skills and the performances have a meaning to the student, yet we find in algebra today a major portion is devoted to operations with algebraic expressions that only an expert mathematician may be called upon to use, developing skills that a majority of students will never use in another subject or in life. I think that we have reason to be discouraged.

Let us be more specific. Any algebraic expression is a function of the letters involved, when these letters are looked upon as symbols for variable quantities, and not abbreviations for words. We readily admit that algebra is a sort of short-hand. But algebra is more than that. We may look upon the expression $5x$ as an abbreviation for something or other, but if we stop there we miss the significance of $5x$ as an algebraic expression denoting a function of the variable x. The fact that we do miss the significance of $5x$ as a function is readily demonstrated when we examine its treatment in any algebra text. We evaluate it for, say, $x=10$. Then we proceed to evaluate another expression, say, $5+x$ for $x=10$, or some other value. Can any one see functionality in this procedure? Can the student? Does the teacher have in mind that $5x$ varies with x? Does the textbook writer establish the significance of $5x$ as a function? Why not let the student evaluate $5x$ for many different values of x, tabulate these values, and draw the graph, so that there is no doubt in the minds of any one that $5x$ is a function of x. Must we wait until chapter 12 to graph this simple function?

What about an equation, a simple equation, say $5x=20$? Is there any functionality involved in the equation? Not the way we teach it in algebra. Of course, we are afraid to talk about $5x=20$ as representing a line parallel to the y-axis and 4 units to the right. That would be analytic geometry, and every one knows that analytic geometry is taught in college. Now if we were really concerned about not teaching college subjects in high school, then why do we teach college algebra? Giving them college algebra is but an admission that we have only separated

subjects for convenience and not because of any inherent difficulties encountered in teaching them or in learning them. If we had constructed a table of values for the function $5x$, we would readily see, the teacher as well as the students, that in the one case we evaluated the function $5x$ for the given values of x and in the other case we are evaluating x for the given value of $5x$. Yes, indeed, we can teach functionality even when we teach simple equations.

A course in algebra based upon the concept of function could easily be built around the following simple functions: (1) $y=ax$; (2) $y=ax+b$; (3) $y=ax^2$; (4) $y=ax^2+bx$; (5) $y=ax^2+c$; (6) $y=ax^2+bx+c$; (7) $y=c/ax$; and (8) $y=c/(ax+b)$. The tabular representation of each function provides adequate practice in the evaluation of algebraic expressions. The graphs of these functions enable the student to become familiar with the straight line, the parabola, and the hyperbola. The functions result in the following types of equations: (1) $ax=c$; (2) $ax+b=c$; (3) $ax^2=d$; (4) $ax^2+bx=d$, and for $d=0$, the factoring of $ax^2+bx=0$; (5) $ax^2+c=d$; (6) $ax^2+bx+c=d$, in connection with this equation factoring of the trinomial, completing the square, and the quadratic formula can be taken up; (7) $c/x=d$; and (8) $c/(ax+b)=d$. In connection with equation 5 we can teach the factors of the difference of two squares.

The following functions can be reduced to one of the above forms. Such reductions provide all the opportunities for the development of the necessary manipulative skills we need. (1) $A_1x+B_1y+C_1=A_2x+B_2y+C_2$; (2) $A_1x^2+B_1x+D_1y+C_1=A_2x^2+B_2x+D_2y+C_2$; (3) $(A_1x+B_1)/(A_2x+B_1)=C$; (4) $(A_1x+B_1)/(A_2x+B_2)=(C_1x+D_1)/(C_2x+D_2)$.

It is to be observed that most of the formulas used as the characteristic relationships in verbal problems are of the forms of the suggested functions. The necessary operations with simple algebraic expressions are included in the suggested program. Purposely we have omitted the division of trinomials, and the factors of the sum and the difference of two cubes. The course will certainly not suffer for such omissions. Such a course presents all the manipulations we seek to develop in a meaningful manner, and in addition, note that, it affords opportunities for the development and training of functional thinking.

In the tabular presentation of these simple functions we can develop the concepts of ranges, increments, average rates, and the criteria for the recognition of them from tabular values. Ex-

periments have demonstrated that the high school student can and does grasp the meaning of $\Delta y/\Delta x$, which is the criterion for the linear function, that is, $\Delta y/\Delta x = c$, a constant, and of $\Delta^2 y/\Delta x$, which is the criterion for the quadratic function, that is, $\Delta^2 y/\Delta x = c$, a constant.

In connection with the graphs of the functions we can develop the concepts of slope of a straight line, intercepts, initial values, zeros of functions, intersection of loci, graphical solution of equations, and the method of the composition of ordinates.

Presented in the manner suggested above, algebra becomes the very embodiment of functionality. It is safe to say that if the student does not acquire the art of functional thinking in algebra, the probability is that he will never get it, for most of the high school graduates do not go to college, and those that do, very few of them select courses in mathematics.

What about the situation in geometry? Very discouraging. Many a leader in mathematical education, for example, Kline, Perry, Moore, suggested years ago how to reorganize the instructional materials of plane geometry to make them teachable, practicable, and conducive to the development of the art of functional thinking. But so far, at least in this country, very little progress has been made along that line. The inertia is too strong to overcome. Without going into the merits of geometry as a course in mental discipline and in logical thinking, any unbiased observer must admit that as taught at the present time geometry does not develop the art of functional thinking. The geometric figures that are studied are presented as static and not dynamic figures. There is fixation but not variation. There is rigidity but not flexibility. It is true that similarity, proportionality, symmetry, and continuity are manifestations of functionality. But these fundamental concepts are not the primary objectives of the course. Even in the case of similarity, the student sees not one triangle varying under certain conditions which preserve its shape but two triangles, fixed and rigid. It is true that by using the concept of continuity many theorems dealing with lines and circles could be treated to bring out the concept of variation and functionality. But the present treatment resorts to the idea of separate and unrelated propositions.

We have undertaken in this presentation to analyze the art of functional thinking in terms of certain abstract propositions. We have mentioned the types of learnings in mathematical instruction in terms of these propositions. We have outlined spe-

cific ways of developing functional thinking in arithmetic and algebra. We have called the attention of the teachers of mathematics to the importance of functional thinking in an age based upon the discoveries and inventions of science. We have insisted that mathematics classes are the best instructional means of attaining this goal. Whether we accept this challenge or not depends upon many factors which we are not in a position to discuss now. One thing is certain. If the individual teacher of mathematics believes in the significance of functional thinking, and he is determined to develop it in his own classes, then neither the textbook nor the course of study will prevent him from carrying out his plans, neither the school system nor the previous preparation of the students will be unsurmountable obstacles in his path. All that he needs is a strong faith in mathematics and an equally strong faith in his ability as a leader of men.

THE QUIZ SECTION

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1. The temperature of a body is no indication of the total amount of heat in the body. (T or F).
2. A certain spherical ball weighs 8 lbs. and is 5 inches in diameter. What does a similar ball of twice the diameter weigh?
3. An object exactly halfway between the moon and the earth would suffer equal attraction from earth and moon. (T or F).
4. The inclination of the earth's axis is responsible for the climatic zones and the seasons. (T or F).
5. Who wrote "The Sceptical Chymist"?
6. Any real number may be thought of as a complex number whose pure imaginary part is zero. (T or F).
7. $(5.01)^{10}$ is equal to what power of 10 (approximately)?
8. What is the probability of drawing a red queen from an ordinary deck of cards?
9. If a, b, c is an arithmetical progression, and a, c, b a geometrical progression, then c, a, b is a harmonic progression. (T or F).
10. What is the sum of the first one hundred odd numbers?
11. In how many different orders can 5 people sit in a row?
12. How many different hands of 13 cards each can be dealt from a deck of 52 cards?

ANSWERS TO THE QUIZ SECTION

1. T; 2. 64 lbs; 3. F; 4. T; 5. Boyle; 6. T; 7. 107; 8. 1/26; 9. T; 10. 10,000; 11. 120; 12. 635,013,559,600.

WHAT IS RESPIRATION?

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Respiration is an important physiological process and usually considered as characteristic of all living things as it results in a supply of energy for most of the energy-consuming processes in the cells of animals and plants. This paper reports on differences in concepts concerning this term.

A zoology textbook, Woodruff, 1938, says, the "intake of free oxygen by the cell and outgo of carbon dioxide and water, the chief products of combustion, is known as, RESPIRATION." A botany text, Smith, et al, 1942, says, "The mechanism and conditions of energy release and transformation in the cell constitute what is known as respiration" and that it is "essentially a biological oxidation process." A bacteriology text, Salle, 1943, states, "any cellular reaction whether aerobic or anaerobic, capable of yielding energy to the organism, is called bacterial respiration." These statements are representative of college zoology, botany and bacteriology textbooks. Most high school and college biology textbooks refer to respiration as including the steps involved in the exchange of carbon dioxide and oxygen and consider the oxidation of food as a different process, although Curtis et al, 1946, mentions the alternative point of view in a footnote. Three of the college biology texts examined considered it as both an exchange of gases and an oxidation. Several of the latter were inconsistent as they contrast photosynthesis and respiration. Photosynthesis is a chemical reaction involving a reduction and neither the securing of the materials used nor the elimination of the end products is considered as a part of the process.

According to a strict interpretation of many definitions, respiration would not occur in anaerobes. This would mean that respiration would not be carried on by many bacteria, certain worms, arthropods and internal parasites. Many textbooks do not consider such organisms.

Table I shows the results of an examination of more than 30 textbooks of biology, botany, zoology and bacteriology used in beginning courses in high school and college. None is more than ten years old and most have been published since 1940. Each was checked for a definition of respiration and for anaerobic

respiration. This table indicates that most botanists and bacteriologists consider respiration as an oxidation process and nearly all zoology texts define it as an exchange of carbon dioxide and oxygen. There is some disagreement in the biology texts, but most stress gas exchange.

TABLE I.—RESPIRATION AS DEFINED IN VARIOUS TYPES OF TEXTBOOKS

Respiration	College bacteriology (4)[1]	College botany (6)[1]	College zoology (9)[1]	College biology (4)[1]	High school biology (9)[1]
1. An exchange of O_2 and CO_2	0	0	7	1	6
2. The exchange of O_2 and CO_2 with the release of energy due to oxidation.	1	0	2	3	3
3. The release of energy from food due to an oxidation.	3	6	0	0	0
4. Anaerobic respiration considered.	3	3	1	3	4

[1] Number of textbooks examined

Weatherwax, 1942, discusses the development of concepts concerning the term. He indicates that there have been three steps in this development; 1, Respiration was originally considered equivalent to breathing (respiration is derived from two Latin words, *re*, again, and *spirare*, to breathe); 2. Later as more was learned about physiology it meant the exchange of gases; 3. Finally when it was found that the important result was the release of energy and not the exchange of gases this came to be the accepted meaning. Frobisher, 1944, similarly discusses this development of concepts and says, "it has become customary to use the term biological oxidation, and its chemical connotation in the newer sense is quite broad and includes both aerobic and anaerobic respiration."

The approach of the botanists and bacteriologists is perhaps explained due to the structure of plants. Plants do not have any special organs by which they can breathe or "give off" carbon dioxide or "take in" oxygen. They obtain oxygen and release carbon dioxide only by diffusion. Many bacteria do not use free oxygen so that there can be no exchange of gases.

Plant and human physiologies may be used as further illus-

trations. Lucas, 1940, writes, "respiration includes all processes whereby cells of the body are furnished with oxygen for combustion and relieved of combustion products in the form of CO_2." However, another human physiology by Carlson and Johnson, 1941, says, "Broadly speaking, respiration is an oxidation phenomenon, a combustion process" and, "The important feature of this reaction from our present point of view, is not the chemical end products." A plant physiology textbook, Miller, 1938, states that it is "a process that goes on in every living cell whereby energy is released in a form that is available to the protoplasm."

From the point of view of this writer it seems that the science teacher should stress that the important result of respiration is the release of energy as the exchange of gases may not occur in all living cells. Although historically and according to many animal physiologists the exchange of gases is considered as respiration.

The writer wishes to thank Dr. Mary A. Bennett for suggestions regarding material in this paper.

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Echo-sounding equipment, of a type developed for the Navy during the war, has a transmitter that produces a supersonic impulse to send vibrations to the sea bottom if within 200 fathoms. The returning echo is picked up by a receiver and converted into electrical energy that actuates the automatic depth-recording mechanism.

THE ORDER OF OPERATIONS IN ELEMENTARY MATHEMATICS

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Within the past year two articles on the order of operations in computation have appeared in SCHOOL SCIENCE AND MATHEMATICS. Both of the two authors mentioned that the question is of minor importance, but nevertheless it is one which teachers have to deal with sooner or later. Actually, the situation provides an excellent opportunity for helping students understand the nature of mathematical symbolism.

The problem of communication which is involved is perhaps best illustrated by a numerical example like $24 \div 3 \times 2$. This expression may represent either 16 or 4, depending upon whether the operation of division or of multiplication is to take precedence. There is no logical basis for a decision on the order of operations in this situation.[1] It is a matter which must be settled by agreement or convention. Some authors of elementary texts ask the reader always to do multiplications first; others permit him to do the indicated operations in the order in which they occur. As long as either of these conventions is adhered to, consistent results follow. The answer to the question as to which convention is preferable must be sought in terms of convenience, and of consistency with a more extensive set of operational procedures.

The parenthesis as a symbol of grouping is firmly established. In expressions of the type $a+bc$ the convention that multiplication is to be done first is also universally accepted. Thus $a+bc$ is treated as $a+(bc)$. The wide acceptance of this convention makes it possible to dispense with the parenthesis in this and similar situations, and thus illustrates the tendency of mathematicians to choose notations in terms of *simplicity* and *economy*. There is no logical reason why the expression $2+4\times5$ should not be evaluated as 30. Doubtless merely the fact that in $a+bc$, as ordinarily written, b and c have a closer spatial association than a and b has resulted in the dominance of the multiplication relation. If addition is given precedence, the dis-

[1] The argument in the article by Mr. Neureiter in SCHOOL SCIENCE AND MATHEMATICS for June, 1946, contains a logical fallacy. His "identity" (5a), namely $(a+b)\cdot c = a+b\cdot c$, on which the argument is based, "begs the question."

tributive postulate of algebra could be written $a+bc=(ac)+(bc)$ This looks a bit queer, but a few numerical examples suffice to convince students of the existence of the relation. Such considerations properly developed can help them come to see that the choice of mathematical notations and conventions is the result of historical circumstance and convenience, and not of logical necessity or inexorable "law." There is not one "right" answer or rule, excluding all others as "wrong."

Turning back to the expression $a \div b \times c$, if one adopts the convention that the indicated multiplication is to be done first, what does he gain? First, this convention is consistent with the corresponding one in $a+b \times c$. Second, this convention permits the commutation of b and c, but the alternative one does not. Then $24 \div 3 \times 2 = 24 \div 2 \times 3 = 4$, whereas if division takes precedence $24 \div 3 \times 2 = 16$, but $24 \div 2 \times 3 = 36$. The "order in which they occur" convention makes the result dependent upon spatial arrangement. It has the effect of making the closeness of operative association of the numbers shift from multiplication to division depending upon the order in which they are written. Thus under both conventions $24 \times 3 \div 2 = 36$, and the 24×3 is treated as more closely associated than the $3 \div 2$. In $24 \div 3 \times 2$, however, the "order in which they occur" convention makes the division association stronger than the multiplication association. The other convention maintains the supremacy of the multiplication association in both cases, and also follows closely the corresponding situation in $24+3 \times 2$ or $24+2 \times 3$.

Many writers have suggested that one can escape the dilemma by avoiding the symbol $\div$, and using instead the parenthesis or fraction bar, which performs as a symbol of grouping. This is undoubtedly the best practice. To insist upon it without taking the opportunity to discuss the problems of communication involved is, however, to overlook an opportunity for teaching above the routine level. Moreover, now and then a student will solve a formula like $i=prt$ in the form $p=i \div rt$. The close spatial association of r and t, or past experience with the relation, results in the omission of any symbol of grouping for r and t. If the student then substitutes numerical values, for example $i=54$, $r=.06$, $t=3$, he may write $p=54 \div .06 \times 3$. The spatial association here may be less close, and he is face to face with the need for the convention under discussion. If the "order in which they occur" convention is followed, the result is absurd in a practical sense. If the "multiplication first" convention is

used, the result conforms to the realities of the underlying simple interest problem, and moreover, the principle "multiplication first" conforms with the accepted convention when addition or subtraction are also involved.

On the other hand, if a student writes the Fahrenheit-Centigrade relation in the form $F=9\div5\times C+32$, or $F=9/5C+32$ as it is sometimes printed, the "multiplication first" convention would result in faulty communication. Similarly, forms like $C=5/9(F-32)$, or $S=n/2(a+l)$ which appear in some books, are misleading, but $C=5(F-32)/9$ and $S=n(a+l)/2$ are not. The criterion of effective communication demands that, what ever the convention may be, the writer of mathematics must avoid notations which permit an ambiguous interpretation.

A word or two about the exponent notation may be in order here. In the symbol ab^n, the exponent n is closely associated with the base b. The accepted convention calls for the numerical computation of b^n before multiplying by a. If, however, both bases have the same exponent, as in a^nb^n, then the theorem expressed by $a^nb^n=(ab)^n$ states that if desired *the multiplication of the bases may precede* the operation indicated by the exponent. Rare indeed is the textbook which states in full the conditions under which this theorem holds. Thus if $a<0$, $b<0$, and $n=1/m$, where m is an even integer, the theorem fails. For example, if the usual conventions with respect to the treatment of complex numbers are followed, $(-4)^{1/2}(-9)^{1/2}\neq(-4\cdot-9)^{1/2}$. Students occasionally run into difficulty in checking the roots of a quadratic equation because of failure to observe these restrictions.

A careful consideration of order of operations in arithmetic and in algebra should be effective in reducing formalism and in avoiding the occurrence of errors. The "canceling" of terms in the reduction of fractions, the replacement of $(a^2+b^2)^{1/2}$ by $a+b$, and similar errors, are at least partially the result of an inadequate conception of the role of symbolism in the control of the order of the indicated operations.

A NEW DISTRIBUTOR FOR FILMS

The JAM HANDY Organization has named Nate Quillen distributor in the eastern and southern sections of Ohio for their School Films Division, according to Frank A. Gauntt, manager.

Mr. Quillen brings to his new position 14 years of experience with The JAM HANDY Organization in the field of audio-visual aids and their utilization.

AIR CRUISES BY RADAR OVER THE BARRACKS FLOOR

ROSCOE E. HARRIS

Bell & Howell Electronics, 1340 Deerfield Road, Deerfield, Illinois

RADAR LEARNS TO FLY

You have heard the story of Radar. Perhaps the story seemed amazing. If so, its sequel should be intriguing. The sequel is the story of the radar trainer. The story of the device that, without leaving the ground, takes the flyer up and out to world exploration and to combat over enemy territory; that guides his flight through overcast and around storms and other hazards as surely as though he were in visual contact with the ground; that does this at no cost in gasoline and flying time to the aircraft or air sickness to him.

Radar was a synonym for magic during the war. In the early days even the mention of the word "Radar" around the cocktail lounges of Washington caused a hushed silence of awe, then the wily departure of several smooth looking gentlemen for a secret conclave with their chief,—probably followed a few days later by an invitation to the officer who had spoken this "naughty" word in public for a chat with his own chief, G-2.

With the aid of these 30 ton pinnacles of perception we guarded our harbor defenses when the submarines menaced our ports. We anticipated an air invasion. If this happened, not only could we be warned of approaching enemy air craft hundreds of miles before they came to our defenses, but if some of them were so unfortunate as to penetrate to our shores in a protective overcast, other radar would direct anti-aircraft fire to blast them from the skies. Taking the offensive we carried the warfare to the enemy. We reduced the weight of radar until our bombers became equipped with miniature sets whose purpose was to locate and identify objects on land and sea through darkness, clouds or smoke; to provide navigation data and a homing signal from its base; and to act as a precision bomb-site on targets otherwise undetectable. Then precise and devastating raids on enemy targets were possible through a concealing overcast and at high altitudes. A trainer was urgently required for such an an airborne radar used on bombers. Such a trainer must make it possible to give bombardier and pilot practice in radar bombing and navigation over a map by presenting him with the same

radar information as he flies a make-believe plane over the map that would be presented in actual flight over the real terrain.

The Physics of Radar

The basic principle of radar has been employed for years. It is said that the Turkish mariners have known, since shortly after they started using salute guns on their boats, how to overcome one of the hazards of their waters recognized by ancient myth. When shrouded in the cold fogs of the Black Sea, a pilot found it difficult to recognize the narrow opening of the Bosphorus from the many false openings that lead only to calamity. A shot from his gun, when near the Turkish shore, sets up a reverberation from the hills of Thrace and Anatolia. If the dimly discerned opening is truly the Bosphorus, the prolonged symphony of sound returning from the tortuous crevasses is as familiar as a childhood memory and he proceeds on through the strait to the "Golden Horn" with complete assurance. But a strange response to his challenge warns him to seek another opening. While this basic principle of radar, the observation of a reverberation pattern from a short blast to recognize fixed landmarks, is not modern, the art of shortening this blast to a millionth of a second (a microsecond)* of very high frequency radio waves instead of sound and of receiving the echoes not as a medley of tones, but as green spots exactly arranged on an oscilloscope screen to present a map of the invisible area, is as modern as—RADAR.

Figure 1 shows a plane equipped with radar in flight over a section of the Mediterranean near a city or a bay. A reflector near the nose of the plane sends out a series of these microsecond pulses sweeping out an area of a very thin, vertical, fan-shaped beam will point in any direction that the antenna is pointed. In search it rotates around and around, thus covering the entire landscape in one revolution of about 20 seconds. As the artist has drawn it, this area is momentarily directed almost 90 degrees to the left of the heading of the plane, so that it cuts across a ship in the bay. Just as a pulse leaves the plane, a stream of electrons starts moving out from the center of a screen of an oscilloscope generally referred to as the "scope," located in the plane. If the radar pulse hits some object, such as the ship, an echo will return to the same antenna and will enter the oscilloscope to pro-

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*The "microsecond," one millionth of a second, is the common time unit employed in radar science.

duce a green spot where the electrons are hitting. The pulses recur several hundred times per second while the reflector scans the region. As the scanning reflector starts each pulse out in a slightly new direction, so each succeeding stream of electrons starts out from the center of the scope in a similar new direction and thus registers echoes from other elements of landscape in their proper directions. It is as if you were perched on a high platform while watering the lawn with a garden hose. Slowly you move the direction of the hose nozzle outward from the spot below you to the limit of a circular field, then quickly jerking it back to center, move it outward again in a slightly new direction, thus advancing the pattern until the entire circular area below is wetted. Now assume that a mischievous boy is manipulating the hose connection so that, due to some impish impulse, he turns the water on and off in such a manner as to permit it

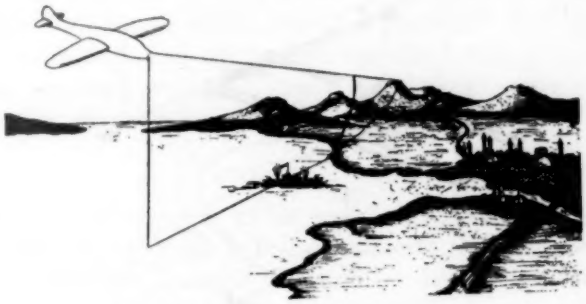

FIG. 1. Locating a ship by radar.

hitting only well defined spots as you scan this area. You then have traced a map pattern on the grass corresponding to the action of the oscilloscope on the aircraft. Whatever may have inspired the boy at your hose connection, the impulse that supplies electrons to be fired in the direction the "gun" of the oscilloscope is momentarily pointing is a returning echo from some object hit by the pulse that started at the same time the outward sweep of the electron gun started.

In radar phenomena everything happens very fast because the speed of the radio beam is the speed of light, 186,000 miles per second, or 320 feet in one microsecond. The narrow pulse of about this thickness is shown racing down the fan shaped area coming from the nose of the plane of figure 1. It has just reached the coast line 20 miles away. A short time before this it had hit the freighter ten miles away and its echo is just now

triggering the electron gun to cause a spot on the scope representing this target. This round trip too, 330 microseconds. The coast line echo will arrive later and leave its imprint farther from the central starting point.

Reducing Radar to Map Scale

Now we wish to reduce this phenomenon to a map size. We are not permitted to modify the scope. We must trigger it with the same high frequency pulse that is used by the radar, hence we must manage to slow down the wave if it is to cover the short map distance in the same time that the radar wave covers the actual landscape. We cannot change the speed of light. Sound travels slower. Can we use sound? Sound in air has a velocity of about 1000 feet per second or about one millionth of the velocity of light. This might do, except that the "pitch" of this

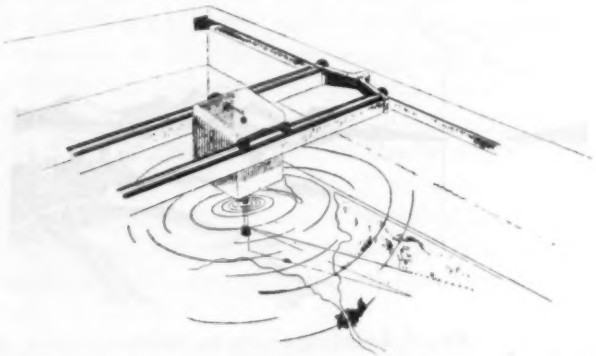

Fig. 2. Supersonic water waves used to simulate radar operation.

supersonic sound, which is fixed by the radar circuits, is so great that the distance between air molecules would be much greater than the amplitude of the vibrating supersonic source. In other words, we simply cannot shake the air molecules that fast. Water can carry such sound waves. The speed is greater; in fact just about 1/200,000th that of light. Could we use supersonic water waves over a map to the scale of 200,000 to 1 and simulate the radar operation? We can, and Figure 2 shows how.

The source of sound is a very thin wafer of quartz immersed in water and forced to send out a supersonic pulse of 15 million vibrations per second for one microsecond. This beam is spread out into a thin vertical fan which may be rotated over a map on the bottom of the tank of water. In fact, everything is identical to the radar except that the radiation is now actually

supersonic waves in water rather than radio waves through space. The crystal may be flown in any direction, being supported by a trolley on a movable bridge, and it may climb or dive in simulation of an actual flight. The map over which it flies is made of plastic. Water areas of this map are smooth, while land surfaces are like fine sand paper, and cities or outstanding radar targets, are crystals of carborundum.

And so the radar seeing mechanism is removed from its aircraft mounting and grafted to the floor of an olive drab building in the middle West. Instead of soaring about in the air, it permanently faces this gray wall. True, its "muscles" still operate. It may spin around and around or stop and search in any sector. It may tilt up and down. But no longer does the radar beam give to it the power of sight. It is as if the eye were injured beyond repair, except that the optical nerve being intact, were stimulated by some strange external forces such as electrical impulses from sound waves and as if the nerve and brain now "sees" the sound, and the optical muscles formerly used to direct the eye itself were now connected through some new communication channels to control the source of sound.

Flying a Mission

When the prospective radar operator first sees the trainer equipment, he no doubt is feeling some of the despondency of the newly blinded, because his ambition has been to become a pilot. Instead of commanding his own ship over new lands he finds himself confined to the prosaic middle west, with a six by ten foot pool of water, a perplexing jumble of wires and electronic chassis, and a radar that too should be airborne, but is confined to this same hum-drum barracks.

He is briefed in his first trial mission, a flight from Alexandria, Egypt, up into the Dodecanese on a "milk run" search for enemy supply lines. He is given wind, air speed, original heading, and a "bon voyage." Since the first two hours of his flight will be over waters under friendly control, he will skip this easy leg. Just as the plane is passing over an island between Crete, visible on the scope 50 miles to his left, and Rhodes about the same distance to his right, he starts piloting by radar. See Figure 3. Ahead, he sees the large island over which he is flying, reaching out to the right. A few scattered islands lie ahead of him, but generally only open sea greets his eye. He has already forgotten that those islands are only particles of grit in a tank of water.

They are as real as they could be if seen through an overcast by radar from the position he is now simulating. He checks the wind and his course from the departing land forms, observes his altitude and notes a small storm center to the West, but nearly 100 miles away. Of course he knows there is no danger from this storm, knows the instructor has just dropped his handkerchief into the water a few feet away from the black box that is his plane. But he judges it as if it were a real storm and logs its position and distance.

Twenty minutes have passed quickly. Islands are now appearing all about him. There to the right is Cos, the birthplace of Herodotus, and at the left, other islands famed in history and

FIG. 3. A trial mission above the Dodecanese.

myth. Each landfall is on schedule. He is flying! Another fifteen minutes and he realizes that, after all, his mission is to search these waters for targets not shown on his map, possible targets for bombing. So just before reaching the island of Icaria, famed in myth for unfortunate flight, he directs his plane on a new course and experiences the sensation of seeing the scope picture swing into a new position. For his plane heading seems to be straight up the scope with the landmarks passing to the right and left as they would in a normal "contact" flight. Just as the passing landscape on such contact flights seems to the novice to tilt on edge and rotate madly around in the most confusing

manner as the plane goes into a steep bank and turn, so to a much greater extent does the scope become confused as the relatively permanent picture starts shifting and rotating during maneuvers of the plane. He decides that the next turn he makes will be with the "azimuth stabilized." The North will then always appear at the top of the scope, being held there in flight by the ship's compass if azimuth stabilization is turned on. Then the map will stay fixed and his changing direction will show as a "lubber line" flashing across the oscilloscope once each cycle pointing out his changing direction, showing that he is moving around the map instead of the map moving around him.

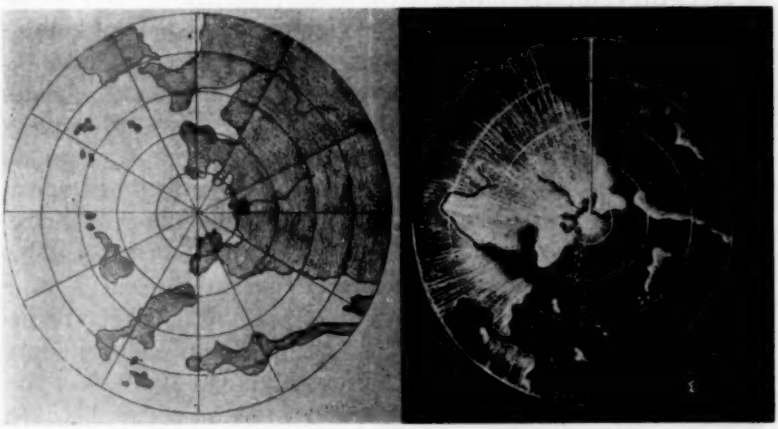

FIG. 4. The radar operator above the center of the map.
FIG. 5. His view from the center.

After ten minutes of this course he realizes that the land ahead is the Asiatic mainland. This is forbidden territory under a neutral flag, so again swinging to the right, he heads South and East, paralleling the coast. There, a village deep in the bay, is beginning to show on the scope. Were it not for the "thick soup" in which he is flying, he might see its slender minarets and white mosques as he nears it as the artist saw it in figure 1. This city is not a military target, but a neutral, enemy barricaded, port. In one of the antenna's periodic revolutions, however, a new target appears in the water area not shown on his charts. This is it! Just as he would subconsciously jerk his head to his left to get a sharper view of this new object, so now he stops the casual "looking around" of his antenna and quickly fixes its

gaze here. He has forgotten the tank of water in the mid-western barracks as he eagerly spies out this middle Eastern target, and this nerve stimulus must cause the water immersed crystal to stop its continuous rotation and bear in this direction with as little delay as would be entailed in turning to look down on such a ship. He is now located at the center of the map shown in Figure 4. What he now sees on the scope is shown on Figure 5. Some distortion is evident. Nearby objects seem relatively closer. In each map, circles are drawn at ten mile intervals. These circles are automatically swept onto the scope by internal electronic operations.

It is time for action. He directs the pilot into a long turn, as he gives the compass control of the scope presentation and opens his altitude circle. He now sees the view of Figure 6. This bombing circle causes distortion because every point on the edge of the hole is the point just below the plane! That kind of map does not look real and does not exist off the scope. However, it is a useful hole because it tells the altitude of the plane. Such a "hole" in the scope is inevitable if its sweep starts just when the radar pulse starts because there are no objects between the aircraft and the water below to return an echo. So there will be an empty hole surrounded by a bright ring due to echoes from the water just below. The center of this hole is likely to be cluttered with electrical surges from the pulsing mechanism, but its rim can be observed with precision. Flying at 30,000 feet the ship is almost lost in the sea return. Distortion occurs because objects 10 miles from the point just below him as "seen" along a diagonal $11\frac{1}{2}$ miles away while the ground itself is $5\frac{1}{2}$ miles away.

As his aircraft heading comes around to the target, he snaps the altitude circle off his scope and reduces his scale to a four mile range. Since this is less than his altitude, it is necessary to be able to remove the altitude circle. The switch that does this simply delays the outward sweep across the oscilloscope until the first ground echoes are received. He now sees Figure 7. In this short range no land forms appear. He sees only the target, faint range circles a mile apart, the heading of his plane, the lubber line, and an additional brighter circle. This is the bombing circle set by computer dials. It flies with the plane. When the target touches this circle is the exact moment to release the bombs. Carefully he directs the heading of the plane so that the combination of wind and air speed will cause him to pass di-

rectly above his target, and waits for the bombing circle to intersect the target.

But now pangs of uncertainty cause his fingers to tremble. The target is a ship. No doubt it is carrying contraband goods. But does it fly the Star and Crescent of a friendly neutral or the Swastika of the enemy? This the radar does not tell!

"Oh, Well, so what? After all, that is only a glass bead on the bottom of the tank."

Being assured that no international complications are going to occur over this; as the bombing circle and the target signal contact, he presses the "bombs away" button and his mission is over. In actual flight he would continue to watch that spot

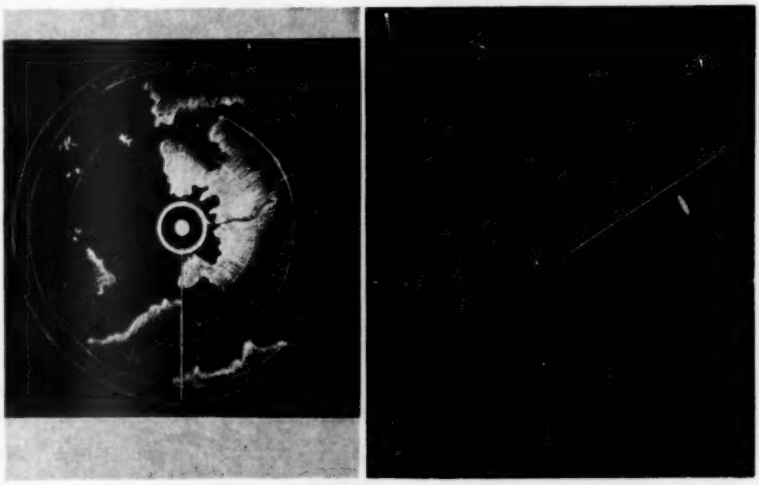

FIG. 6. Distortion caused by the bombing circle.

FIG. 7. Range circles a mile apart.

marked on the target as the pilot takes over to move out. He might even see his bomb going down after several seconds as a moving speck, and, after a out 43 seconds, see this moving speck join with the target spot, see a sudden flare, then all disappear.

But in the midwest training barracks results show as a red ink line indicating his course during the mission, the point of bomb release and the point of bomb impact.

TRAINER-RADAR COUPLING

This simulated flight was accomplished with amazing reality.

How is it done? Figure 2 shows the bridge and trolley which contains much of the essential equipment. The trolley, to the bottom of which the crystal is fastened, may be moved along bridge rails in an east-west direction for the flight just described, and the bridge itself moved North and South. Thus wind and aircraft speed may be introduced by motors driving wheels and

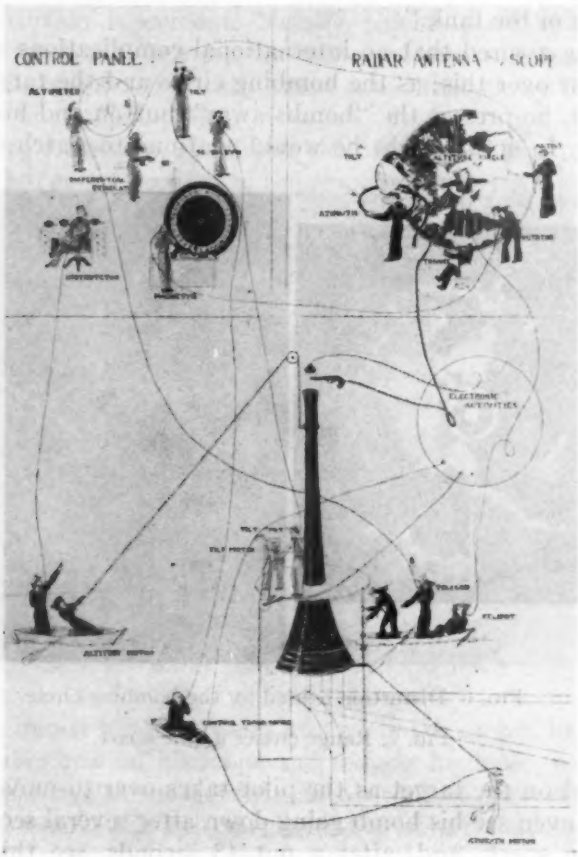

FIG. 8. An artist's view of the radar at work.

drums at the correct speed. Straight and level flight is easily simulated but a great many things must be co-ordinated.

If personnel were used to do these things, rather than motors, selsyns, magnesyns, telegons and other weird electro-mechanical equipment, it would require a joint Army-Navy operation. The artist has imagined such personnel at work as shown in Figure 8. The supersonic equipment is a tin horn dipping into

water with the control panel, the radar components, and the "electronic activities" surrounding it. The radar, with its director (the trainee) seated before it, has an antenna shown as a search light with its crew of two, a "tilt" and an "azimuth" operator. Note that the connection to the light is broken and instead is brought down through "electronic activities," and, rather than activating the original radar beam, triggers a supersonic pulse. This is shown schematically by a pistol above the horn. The short blast of sound is directed down under the water to a glass reflector so shaped as to direct the pulse out through the required fan shaped area over the bottom map. Returning echoes strike the reflector and are converted to electrical impulses by the microphone above the mouthpiece of the horn in this imaginative picture. Actually, the same thin quartz "Piezo electric" crystal, not only vibrates when energized by electrical waves, but sends back electrical waves when hit by the returning sound waves. It acts like a telephone receiver in changing electrical waves to sound, and like a telephone transmitter in changing sound waves into electrical waves. These electrical waves are then changed by "electronic activities" into signals acceptable to the radar. The rotation of the sweep across the scope, as well as the flash of the lubber line, is connected to the rotation of the radar antenna. But the supersonic beam must be rotated in unison with the radar and the "zero sweep," that is the one pointing down the assumed heading of the plane, must be made to appear in the desired direction. Thus the antenna moves as the "Trainee" directs his "Tilt" and "Azimuth" crew, but its motions must be repeated perfectly by the equipment in the water. The watcher "SELSYN" with binoculars trained on the radar antenna gives azimuth information to the sailor "CONTROL TRANSFORMER" in the boat, who tells the diving-suit clad "AZIMUTH MOTOR" what to do and relays power to him. In the same way an observer watches the tilt operator to inform the "TILT POT," who must tell the "TILT MOTOR" what to do and control the power to him. An "Artist" paints on the pattern along a scope sweep when signaled from the supersonic echoes and in positions around the scope by direction of "DIFFERENTIAL GENERATOR." Since the supposed heading is known only at the "CONTROL PANEL," this observer, "DIFFERENTIAL GENERATOR" must watch the direction of the supersonic beam and tell the "Artist" just where to paint in the pattern. If the "Instructor," sitting before

the desk, changes heading, all he really does is to set a local dial. Then it is up to DIFFERENTIAL GENERATOR" to instruct the "Artist" where to paint this pattern. But, if the "Trainee" wishes to control the azimuth by keeping north at the top of the scope, the "MAGNESYN" clerk must be alerted. He also watches the supersonic beam end and, when it is directed north, commands the "scope rotator" to see that the signals are now straight up. This makes the "Artist's" job easier as he seems to paint on the signals at the same places regardless of heading although the lubber line flashes out at different places. Altitude is controlled by the "Instructor" who signals his wishes to the "ALTITUDE MOTOR." But the "ALTIMETER" is set by information sent by "TELEGON" who is in the boat with the altitude sounding sailor and the "HELIPOT" sailor. Thus "ALTIMETER" registers the movements of the altitude motor crew, and the "Instructor" knows when to signal "cease action" to his crew by watching this dial. "HELIPOT" sends messages by way of "electronic activities" to the "ALTITUDE CIRCLE" on the scope. This hole may be opened at the wish of the "Trainee" to give him the height information.

Of course these little soldiers and sailors are purely a figment of the imagination of the artist. However, these functions must be performed. Names shown in capital letters are actual instruments that perform these facts of remote control. Occasionally "Gremlins" infiltrate to create mysterious malfunctioning, but they are soon repulsed by a "ground crew" of expert technicians and imaginative flights are again resumed over areas soon to become regions of real flight.

This "sequel to radar" obviously must be an involved mechanism if it is to accomplish all of these actions by electromechanical devices. Each unit required painstaking calibration for its every function before leaving the factory. To procure such laboratory precision at a time when procurement of basic components was very difficult, but war urgency demanded speed in production, is another chapter in the story of American Industry's ability to meet war time emergencies. However, the task was justified by results. With this radar trainer the bomber crew was briefed by repeatedly flying over a particular target and bombing it until the crew became letter perfect in a mission before actually flying it. Each briefing exercise could have been slightly different: a squall could force the pilot to approach his target from a new direction; the wind need never

have been the same; sometimes simulated evasion of intercepting enemy aircraft could compel new altitudes and approaches; perhaps counter-radar measures were introduced and a new target must have been selected. The crew must always fly with a realization of cruising range and the distance to a safe port. But, in that FINAL MISSION, if the crew be letter-perfect, the bomb would hit a target that was never seen and was as impersonal as the grain of carborundum on the bottom of the tank of water in an olive-drab mid-western barracks.

INFINITESIMAL PARTICLES HOLD ANSWERS TO SCIENTIFIC PROBLEMS

Locked up in the infinitesimal regions of the dimensional scale not yet uncovered by powerful microscopes are the answers to a lot of questions that have baffled scientists for many years, according to Dr. Linus Pauling, Chairman of the Division of Chemistry and Chemical Engineering at the California Institute of Technology.

Illustrating the size of this miniature world, he asked persons attending the George Westinghouse Centennial Forum to imagine a man whose stature was increased 250,000,000 times. He would then become equal in height to the distance from the earth to the moon and the earth itself would seem to be the size of a billiard ball. A speck—barely visible to the naked eye—would represent New York City.

Through the powerful electron microscope he could determine the size and shape of the Empire State Building but could not be sure of the individual rooms, the scientist explained. Automobiles would appear as specks and human beings would not be visible.

COAL SUPPLIES WON'T MATTER IF SCIENTISTS DEVELOP URANIUM ENERGY

If scientists ever succeed in developing a practical method for utilizing all the energy stored up in uranium, future generations won't have to worry much about dwindling supplies of our natural resource, coal.

This was indicated to participants in the George Westinghouse Centennial Forum in Pittsburgh, Pa., by Dr. Enrico Fermi, Professor of Physics at the University of Chicago, and a Nobel Prize winner for his work on atom splitting. The fission energy of uranium is roughly 3,000,000 times that of an equal amount of coal.

The energy value of one pound of uranium is so great that even an enormous increase of cost of this material may not interfere with its economical use as a source of power. Indeed three million tons of coal, equivalent in energy content to one ton of uranium, cost about eight million dollars. Consequently, as far as the cost of the raw materials, uranium and coal would become equivalent for a price for uranium of $4,000 per pound. Before the war the cost of uranium was about $2 a pound so that an increase of the order of a thousand times the pre-war price would not be necessarily uneconomical.

AN EXPERIMENTAL EVALUATION OF THE SEMIMICRO METHOD OF TEACHING HIGH SCHOOL CHEMISTRY

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The need for a revision of the existing methods of conducting laboratory experiments in high school chemistry has been pointed out by chemistry teachers at various times. An attempt was made between the years 1930–35 to introduce the "Demonstration Method" as a substitute for the usual laboratory procedure. The idea did not, however, meet with the general approval of high school chemistry teachers. Most teachers believed that a laboratory course was necessary in order to develop habits of scientific thinking as well as to correlate and unify the text book material taken during the lecture period.

The fact that the "Demonstration Method" should once have attracted such a large following is, I believe, indicative of the attitude of many teachers today toward the laboratory period. Chemistry teachers are bound to experience a feeling of frustration when they see students repeatedly performing experiments in a sloppy, wasteful manner. How can the teacher help but ask himself whether or not all this expenditure of time and effort is commensurate with the results produced in the student? This feeling of futility grows in proportion to the number of years that the teacher has been supervising laboratory periods. There is a danger that he will eventually look upon laboratory work as a necessary evil which he must tolerate for three hours every week because it is a requirement of the state accrediting association.

On the other hand there are few courses in the high school curriculum which offer so great an opportunity for individual teaching and attention as does the chemistry laboratory course. When properly conducted, it leads to training in manual skills, in the scientific attitude for correct thinking, and in attaining a high degree of accuracy in the methods of observation and deduction. Likewise such simple skills as exactness and neatness, proper penmanship, correct spelling habits, and orderly and clean methods of procedure can be repeatedly taught and emphasized. Then too, students can be disciplined to the point where they pride themselves in the perfection of small details that mark the line of distinction between mediocre and success-

ful work. The theories of chemistry are often forgotten before the next lecture period; sound habits acquired in the laboratory can last a life time. Unfortunately such good habits can hardly be developed if the teacher spends all, or the greater part, of his laboratory period correcting disciplinary problems or doleing out chemicals. From what I have been able to observe this lack of teaching during the laboratory period seems to be the state of affairs at the present time. Obviously some solution to the problem should be found.

In studying this question of simplifying the high school student's laboratory work, I have tried to approach the problem with an open mind and with as few prejudices as possible. While doing this I kept two things in mind: first, the hope of simplifying and cleaning up the student's work as much as possible; and secondly, the hope of creating an atmosphere in the laboratory in which the teacher could conduct a course that would supplement as well as correlate the work of the lecture period. Too often I have felt that an automatic chemical dispenser might readily be substituted for the teacher and the results be just as satisfactory.

In order to bring some order out of the chaos of the laboratory as well as to eliminate the waste that has always been so evident, I decided to introduce the semimicro method, using one group of thirty students as an experimental class. Previous reports of the advantages to be gained by the use of the semimicro method have emphasized primarily economy of operation.[1,2] I did not believe this to be sufficient reason for changing to the semimicro method unless the change also resulted in an improvement in teaching technique.

Since there was at the time no laboratory manual published for semimicro high school chemistry and no existing system that seemed to meet our needs of keeping the course on a high level, I decided to draw up my own series of experiments and to try them on an experimental class. These experiments were used in typewritten form with the students making suggestions and recommendations for changes as they worked the experiments. Some experiments we found could be worked with excellent results merely by changing the quantities of chemicals called for in standard macro laboratory manuals. Others required an

[1] Arthur, P. and Smith, O. "Advantages of Semimicro Technique in Teaching Qualitative Analysis," *Journal of Chemical Education*, 18, 385, 1941.

[2] Schiller, W. and Lawrence, Sister M., "Semimicro Equipment for High School and College Chemistry," *ibid.* 18, 543, 1941.

entirely new technique and different approach. Any procedure which was not convincing to the student was discarded or revised until satisfactory results were obtained. In no case were we obliged, because of the use of smaller apparatus, to sacrifice a procedure or omit any material considered essential to the experiment.

Again, the semimicro method proved to be a time saver; experiments which normally took an hour and a half with the macro method could be done in approximately two-thirds of the time. For experiments of this type we devised a series of questions and additional experiments to fill out the time alloted to the experiment. At the end of the year a rough, but well tested draft of some fifty experiments had been worked out. These needed a complete revision and polishing to make them presentable to a class as a usable laboratory text. This was done during the summer months and the revised experiments hectographed and prepared for the students' use.

For the second stage of the program, it was decided to divide the chemistry classes into two sections in order to determine the difference in attainment, if any, when using the semimicro and the macro method of procedure. Two classes totaling sixty four students were taught the semimicro method and two classes of approximately the same number were used as control classes and were taught the macro method. This latter group used a standard laboratory manual. The students of these classes were not segregated groups. The average IQ of the four classes was 102.8 which would indicate that they were little more than average in intelligence. The same chemistry text book was used during the lecture periods with both classes.

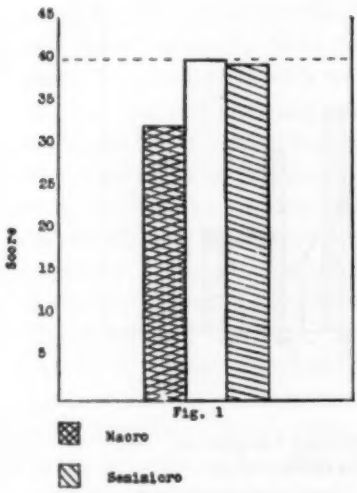
It was thought best at the very outset to put forth a series of specific aims, the attainment of which, we hoped, would tend to eliminate the more objectionable factors in the macro procedure. The aims which we set forth and which were constantly kept in mind during the course of the year, and by which we were willing to impartially judge both groups, were as follows:

1. To instill habits of scientific, orderly thinking by constantly insisting on methods of deduction based on habits of close observation.
2. To instill habits of cleanliness and neatness through careful observation of order of procedure as set forth by the laboratory manual.
3. To instill in the student an appreciation of the scientific method of approaching a problem through a step by step analysis of the contents of the problem and similarly working toward the conclusion. To this end the experiment was presented to the student as a problem which

he was to solve and which could be solved correctly only by a logical and orderly method of procedure.

4. To insist that, when the student completes the course in chemistry, he should know the subject matter of chemistry, as well as laboratory methods, to the point of meeting minimum standards such as those set forth in standardized tests with national normals.

The attainment of the first three of these objectives we were able to observe during the year as the students worked their experiments. We found that these objectives were much easier to obtain in the group using the semimicro method either because of the method itself or because of the added interest the



Graphic Results of the Testing Program

FIG. 1. Persing Laboratory Test National Norm = 40.1

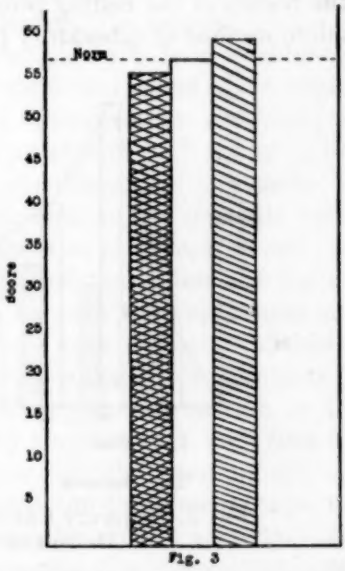


FIG. 3. Cooperative Chemistry Test, Form *Q* National Norm 57.1

student seemed to show when using the semimicro method. We found that the student himself discovered that he easily develop a series of habits which eventually made the working of the experiment easier and the results more convincing and more satisfying.

The fourth of these aims was determined by the use of comprehensive tests at the end of the school year. The "Persing Laboratory Chemistry Test, Form B," (Public School Publishing Co. Bloomington, Ill.) was used to test the students' success in laboratory procedure. The students' knowledge of subject

matter was judged by the results attained on the "Cooperative Chemistry Test, Form Q," (Cooperative Test Service of the American Council on Education). The results of these tests, even when considered in the light of their limitations, completely convinced us that knowledge of laboratory procedure as well as knowledge of the subject matter was acquired in a superior manner by the student using the semimicro procedures. These results were tabulated on the basis of similar intelligence quotients. In both cases the students using the semimicro method scored higher than the students using the macro method. Summarizing the results of the testing program, the students using the semimicro method of laboratory procedure scored 39.4 as compared

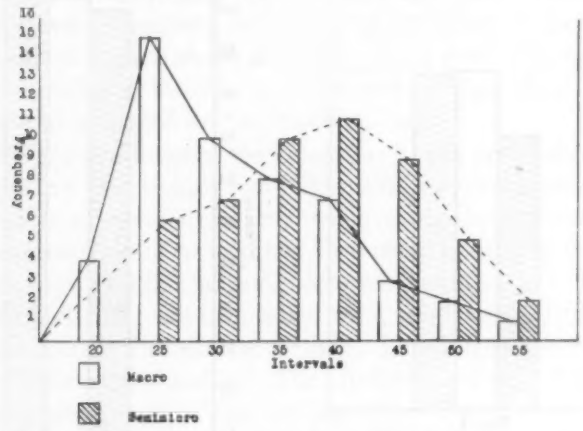
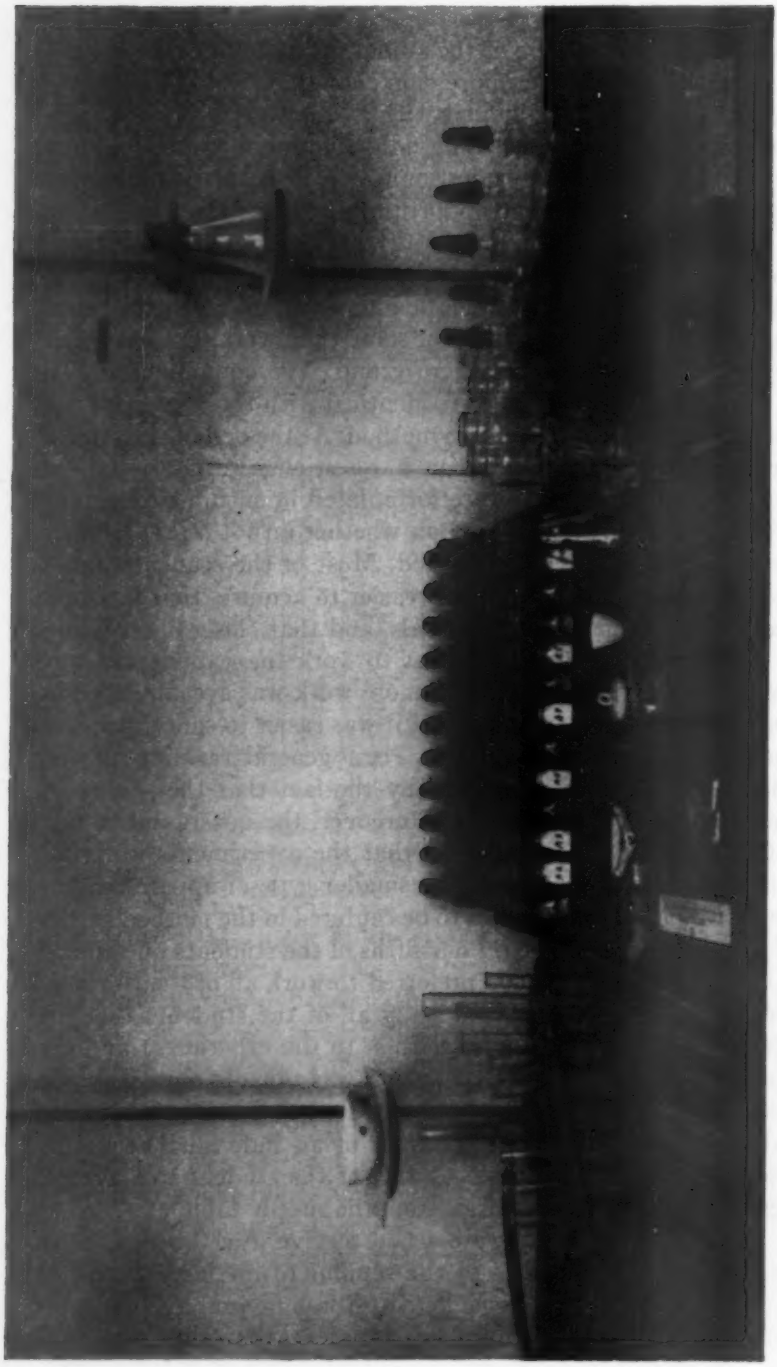


FIG. 2. Frequency Curve for Persing Laboratory Test on Macro and Semimicro Students.

to a score of 32.2 made by the students using the macro method. The national norm for this test was 40.1 (See Figs. 1 and 2). On general comprehension the students using the semimicro method scored 59.8 as against 55.4 scored by the students using the older procedure. The national norm for this test is 57.1 (see Fig. 3). The scores were tabulated on a total of 120 student using the two methods of laboratory procedure. Drawing conclusions on the basis of such a small number of students undoubtedly has serious limitations but one can certainly feel sure that there is no lowering of standards nor loss of knowledge of laboratory methods because of the use of the semimicro method of laboratory procedure. Subsequent testing programs carried out on larger groups of students using the semimicro method have confirmed us in this opinion.

Student reaction to the semimicro method has been good. I was rather apprehensive of the students' attitude toward semimicro; I was under the impression that they would look upon the smaller type of equipment with a "play-toy" attitude. The reactions of the students using only the semimicro procedures were obtained merely by questioning the student and noting his responses when given the opportunity of using the larger type of equipment. However, a definite reaction was obtained from a control group or those using the macro method. During the latter half of one year these students were shifted to the semimicro method and continued for some time working the experiments exactly as the semimicro group. The equipment as well as the laboratory manual were identical with those used by the students taking the semimicro method. At the end of the semester these students were given a questionnaire consisting of twenty questions which were formulated in such a way as not to give the students any lead on whether or not a favorable or unfavorable response was elicited. Most of the students found the semimicro techniques to be easier to acquire, that less care was needed in handling chemicals, and that closer observation to details was necessary in order to work the experiment successfully. They also noted that more work was accomplished in a shorter period of time and that it was easier to concentrate on the results of the experiment. Their general reaction to the laboratory work was indicated by the fact that they found it cleaner and more interesting. Moreover, the questionnaire significantly brought out the fact that the experiments were not more interesting because of the smaller type of apparatus. Interest would therefore, seem to be centered in the method rather than the equipment used. Four-fifths of the students questioned said that they would have preferred to work all of their experiments by this method. Practically all of the students thought that they could pay more attention to the experiment and get better results, when their attention was not distracted by the necessity of leaving their places and standing in line for chemicals at the supply table. (The use of an individual student's reagent tray makes it unnecessary for the student to leave his desk in order to get chemicals from the supply table).

Finally, the students were asked to give in a few sentences, their general impressions of the semimicro method. With but few exceptions the response here also was favorable. It was interesting to note that a number of students were impressed with



Individual student apparatus for the semimicro laboratory course in high school chemistry, showing the student's reagent tray and the acid-base reagent tray.

the odd fact that they could remember more of the experiment when using the semimicro techniques than they could when working other experiments by the macro method. Many commented that there was little noise or disorder in the laboratory and that they liked the class room atmosphere of the laboratory. A repetition of this questionnaire at the end of the year, after the class had been reconverted to the macro method, brought no significant change in the students' attitude toward the semimicro method.

The success that we experienced in the use of the semimicro method with these classes encouraged us to revise and reedit the manual and to use it, together with several other schools, in the mimeographed form. We found that the original results were not misleading. The system has been unanimously accepted by a score of other teachers as an improvement over the older, less exacting, macro procedure. Subsequent revisions and corrections in the mimeographed form and the encouragement received from other teachers finally led us to publish the manual and to adopt permanently the semimicro system as a tried and proven method of high school laboratory procedure.[3]

I do not propose to set forth a series of arguments for the semimicro method of teaching high schooi chemistry, but I would like to point out a few of the advantages of this method.

1. The high school laboratory can be made into a clean, orderly work shop for students, where the teacher can instill fundamental habits of neatness and orderly thinking, as well as accuracy in observing and reporting details of the experiment. The difficulties inherent in the macro procedure, such as overflowing water baths, students pouring chemicals down the drain without having made a single observation, or even becoming aware of the fact that a chemical reaction has taken place, are eliminated.

2. There is a saving of time and effort on the part of the student in working experiments. The same results can be accomplished by a simplified method which at the same time is more in keeping with true educational methods. More work can be accomplished in a shorter period of time. A sense of satisfaction on the part of the student over the results achieved tends to raise the standards of the course.

3. The semimicro method allows for a more flexible program.

[3] Weisbruch, Fred T., *Semimicro Laboratory Exercises in High School Chemistry*, D.C. Heath & Co., Boston, Mass.

It is not necessary that all students' work be parallel and that a given experiment be completed in an alloted period of time. A student can work at his own speed since he has, in effect, his own laboratory at his desk. Likewise, the better student can forge ahead and accomplish as much as he will. The ambitious student can also be directed to follow experiments that extend beyond the scope of the ordinary high school course. The chemistry literature of the past ten years contains many suggestions for short experiments that can be of great advantage to the better student if he is properly directed. The teacher will likewise find many of his disciplinary problems solved,—problems which originate in the mental sluggishness and lack of interest induced in the better student by the necessity of slowing down to the pace of the poor student.

4. The student can be allowed to work as an individual, instead of working in pairs as is commonly done in the macro method. A student on his own and held accountable only to himself for the work he turns in, is bound to be a better student. The usual custom of having one student work the experiment while the other looks on is hardly an educational method that can be recommended.

5. The saving of space for storage of equipment and smaller locker space required for individual apparatus makes it possible for every school to have a chemistry laboratory and the opportunity to offer both chemistry and physics in the junior and senior years.

6. The low cost of chemicals and equipment is an added advantage to those schools whose budget will not ordinarily allow the introduction of a chemistry course. We have never considered this factor of low cost to be any great advantage, as we previously had managed to operate easily within our budget on the macro method. It certainly would not, in itself, be an argument for introducing the semimicro method. The turnover from the macro to the semimicro method can be made at a cost of between $150 and $250 depending upon the extent to which the semimicro method is introduced.[4]

7. The increase in safety when handling small quantities of chemicals is quite evident. Because all acids and caustic chemicals are required only in drop quantities or in a maximum of a few milliliters, the question of dangerous laboratory accidents

[4] See "A Guide to the Introduction of Semimicro High School Chemistry," D. C. Heath & Co., Boston, Mass.

practically disappears. The most serious laboratory accident that we have had in five years of using the semimicro method consisted of mild cuts from the improper use of glass tubing.

8. The laboratory teacher can devote his time to actually "teaching" chemistry during the laboratory period instead of being a mere "dispenser of chemicals." Each student, or group of students, is provided with a student reagent tray containing most of the chemicals needed for the course. The entire atmosphere of the laboratory is one of study and experimentation rather than one of heedless confusion brought on by students rushing around for reagents and leaving trails of caustic chemicals from the reagent shelf to their desks.

One of the main arguments for introducing the semimicro method is the improvement of the student's laboratory technique. It is this improvement in laboratory technique and the resulting improvement in the teaching *method* that seems to be the greatest advantage and the one that decidedly affects the student's as well as the teacher's favorable response to the method.

In no case has the apparatus used in teaching semimicro chemistry been adopted merely for the sake of introducing the smaller type of equipment. Practically all of the equipment is of the standard type used in the college course for semimicro qualitative analysis. The only variation of this consists of 2 oz. wide-mouth gas collecting bottles, funnel tubes of a special type to replace the standard thistle tube, and the students reagent tray. The latter two items are carried in stock by the Wilkens-Anderson Co., Chicago, Ill. Test tubes, test tube holders, test tube supports, Bunsen burners and all such standard equipment is of the usual semimicro variety.

Conclusion: The semimicro method of conducting the high school laboratory course has, in our case, definitely shown itself to be an improvement over the usual macro method of conducting laboratory work. The system is cleaner, more orderly and leads to more accurate and precise method of working experiments. The student, when given an opportunity to work with the semimicro method finds it more pleasing and more interesting Standardized tests in laboratory procedure and in general comprehension show that the student not only does not lose any knowledge of the subject but actually, through greater interest and refined methods of procedure, is able to produce on a higher level than the student using the older macro method of working

experiments. The semimicro method tends to instill habits of accuracy, close observation to detail, and in general, good laboratory habits.

Finally, the instructor has an opportunity to act in his full capacity of *teacher* during the laboratory period. Once the students' reagent trays have been filled the teacher's work of giving out chemicals is finished for the year. He is thus free to advise and direct students during the laboratory period in an atmosphere that is that of a well ordered class room.

CENTRAL ASSOCIATION OF SCIENCE AND MATHEMATICS TEACHERS

FORTY SIXTH ANNUAL CONVENTION

FRIDAY AND SATURDAY—NOVEMBER 29 AND 30, 1946

Book-Cadillac Hotel, Detroit, Michigan

Friday Morning

General Program **9:15 A.M.** **Grand Ball Room**

Presiding: ARTHUR C. BAKER, President of the Association

New Power, Products, and Personnel
Gerald Wendt, Editorial Director, *Science Illustrated*

The Growth of Power and Its Economic Significance
T. H. Davis, Chairman of the Department of Mathematics, Northwestern University, Evanston, Illinois

Tomorrow's Scientists
Watson Davis, Director, *Science Service*

Presentation of Emeritus Memberships
George K. Peterson, Chairman of the Journal Committee, North High School, Sheboygan, Wisconsin

Friday Noon

Annual Association Luncheon **12:00 M.** **Crystal Ball Room**

Presiding: IRA C. DAVIS, University of Wisconsin, Madison

Previews of Progress (A new and startling stage demonstration of the miracles of science.)
Allen Orth, Director of Educational Service, Public Relations Department, General Motors Corporation

Friday Evening

Annual Banquet **7:00 P.M.** **Grand Ball Room**

Toastmaster: O. D. FRANK, School of Education, University of Chicago

Radar and Microwaves
J. O. Perrine, Assistant Vice President, American Telephone and Telegraph Corporation

Saturday Morning

Annual Business Meeting **8:15 A.M.** **Founders Room**

General Meeting **9:00 A.M.** **Crystal Ball Room**

Annual Business Meeting

Presiding: CHARLOTTE L. GRANT, Vice President of the Association

Science, General Education, and the National Welfare

Frederick L. Hovde, President, Purdue University

Adjourn to Group Meetings

SATURDAY AFTERNOON TRIP

(Free. Capacity limited to 300. Reservations of members will be given priority in order received. Reservations for non-members will be honored if space permits.)

Saturday 12:15 P.M.

By Buses

Chairman: MELVIN YAHNKE, Edison Institute High School, Dearborn, Michigan

Co-Chairman: MAX IRLAND, Edison Institute High School, Dearborn, Michigan

Trip to Rouge Plant, Greenfield Village, and Edison Institute Museum. *Buses will leave the Book-Cadillac Hotel at* **12:15** *p.m.* (12 buses in all) Buses will arrive at Gate 4 at 1:00 p.m.

There will be a short tour of the Rouge Plant, pausing at the Coke Ovens, arriving at the Open Hearth Building at 1:15 p.m. to disembark.

Placards will be used to explain the tour; if the final assembly line is working, that will be visited instead of the Pressed Steel Building.

Buses will leave the Rouge Plant at 2:15 p.m., arriving at Greenfield Village at 2:25 p.m.

Buses will leave the Edison Institute Museum to return downtown at 4:30 p.m.

Mr. Donaldson will arrange box lunches on the buses.

Mr. R. H. McCaroll and Mr. W. S. James will address visitors in the Edison Institute Museum Theatre on the topic:

WHAT FORD ENGINEERS ARE THINKING ABOUT FOR THE FUTURE

Conducted tours through the village and museum will be arranged.

SECTION MEETINGS

Friday 2:15 P.M.

Biology **Normandie Room & C**

Chairman: FRED J. BURDINE, Thornton Township High School, Harvey, Illinois

A Chemist Looks at the Manufacture and Control of Pharmaceuticals

J. Russell Bright, Director of Control, Gelatin Products Corporation, Detroit

Filming for Your Science Classes

Ella M. Clark, formerly of Detroit Northwestern High School Biology Department

Conservation Education Camp for Teachers, Versailles State Park

Howard H. Michaud, Associate Professor of Conservation, Purdue University

Chemistry **Reception Room of Grand Ball Room**

Chairman: WALTER C. GEISLER, Shortridge High School, Indianapolis

Coal Tar Products in World War II
Frank Cislak, Chief Chemist, Reilly Tar and Chemical Company, Indianapolis
Chemical Industries of Norway and Sewden (Personal observations)
Thomas Vaugh, Wyandotte Chemical Corporation
Atomic Energy
George Calingaeit, Ethyl Corporation, Detroit
Display—What Others Have Done (Home-made teaching aids)

Elementary Mathematics **English Room**

Chairman: Ross Herr, Trumbull School, Chicago

An Overview of a Meaningful Program in Arithmetic
Irene Sauble, Director, Exact Sciences, Detroit Public Schools
How Arithmetic Is Taught Meaningfully
Dorothy Yates, Coolidge Elementary School, Detroit
Changing from a Mechanistic to a Meaningful Program of Arithmetic Instruction
Paul D. Carter, Director of Curriculum, Birmingham, Michigan

General Science **Sample Room**

Chairman: W. A. Porter, University High School, Madison, Wisconsin

Preparing Pupils to Live in a New World
Morris Meister, Principal, Bronx High School of Science, New York City
Organizing the General Science Laboratory for Individual Work
Ira C. Davis, Professor of Educational Methods, University of Wisconsin, Madison

Geography **Founders Room**

Chairman: Laura Kahler, Silver Burdett Company, Chicago

Maps of National Power
Clarence Woodrow Sorensen, Special Lecturer in Geography with the Community Program Service, University of Minnesota, Minneapolis
A Demonstration Lesson in Geography
(By a classroom teacher under the supervision of an elementary supervisor from one of the Detroit communities.)
The lesson will deal with changing adaptations to the environment due to technological changes.

Mathematics **Grand Ball Room**

(Meeting in cooperation with the Detroit Mathematics Club)

Chairman: Glenn F. Hewitt, Von Steuben High School, Chicago

Some Industrial Effects of Quality Control by Statistical Methods
Lloyd A. Knowler, Associate Professor of Mathematics, State University of Iowa
Matching People and Jobs
Arthur S. Greiner, Assistant Cashier, National Bank of Detroit

Physics **Crystal Ball Room**

Chairman: Eiffel G. Plasterer, High School, Huntington, Indiana

The Teaching of Laboratory Work in High School Physics
R. W. Lefler, Department of Physics, Purdue University

Rubber and Plastics in the Science Courses (Lecture-demonstration and slides)
H. E. Brown, Technical Department, W. M. Welch Manufacturing Company, Chicago

Saturday 10:00 A.M.

Elementary Science and Elementary School Group **English Room**

Chairman: HILDEGARD C. PIEPER, Bret Harte School, Chicago

Elementary Science for Society
Illa Podendorf, Laboratory School, University of Chicago
Science Activities Contribute to Personal Development

Albert Pilts, Acting Directing Teacher in Science, Roosevelt School, Detroit

Junior High School Group **Reception Room to Grand Ball Room**

Presiding: JAMES HARDIMON, Regional Director, Young America Films, Inc. New York

Food Education
Paul H. Jones, Director, Garden Educational Service, Ford Motor Company, Detroit
Mathematics in the Junior High School
H. Vernon Price, Head of Mathematics, University High School, State University of Iowa, Iowa City

Senior High School Group **Crystal Ball Room**

Presiding: NATHAN A. NEAL, Radio Department, Board of Education, Cleveland

The Atmosphere of the Sun
Orren C. Mohler, Assistant Professor of Astronomy, McMath-Hulbert Observatory, University of Michigan
The University of Michigan has a motion picture solar observatory; Dr. Mohler will present recent motion pictures from this source.

Junior College Group **Normandie Room & C**

Presiding: J. R. MAYOR, Southern Illinois Normal University, Carbondale, Illinois

Social Implications of the Power Age
Melvin J. Segal, Assistant Professor of Social Science, Basic College, Michigan State College, East Lansing
Some Observations on the Teaching of Elementary Collegiate Mathematics
T. H. Hildebrandt, Professor of Mathematics, University of Michigan

Conservation Group **Founders Room**

Presiding: HOWARD H. MICHAUD, Assistant Professor of Conservation, Purdue University

Forests and People
Samuel T. Dana, Dean of the School of Forestry and Conservation, University of Michigan
People in the Out-of-Doors
Roberts Mann, Director of Conservation, Forest Preserve District, Cook County, Illinois

PROBLEM DEPARTMENT

CONDUCTED BY G. H. JAMISON
State Teachers College, Kirkville, Mo.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution or proposed problem sent to the Editor should have the author's name introducing the problem or solution *as on the following pages.*

The editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to G. H. Jamison, State Teachers College, Kirksville, Missouri.

SOLUTIONS AND PROBLEMS

Note. Persons sending in solutions and submitting problems for solutions should observe the following instructions.

1. Drawings in India ink should be on a separate page from the solution.

2. Give the solution to the problem which you propose if you have one and also the source and any known references to it.

3. In general when several solutions are correct, the one submitted in the best form will be used.

LATE SOLUTIONS

1981. *Proposed by J. F. Arena, Boone, N. C.*

Evaluate the integral

$$\int x^3\sqrt{x+a}\,dx$$

without the use of table of integrals.

Solution by V. C. Bailey, Delaware, Ohio

Integration-by-parts formula

$$\int ud\,v = uv - \int v\,du$$

must be used three times. In successive applications of the formula, let

$u=x^3$ and $dv=(x+a)^{1/2}dx$,

$u=x^2$ and $dv=(x+a)^{3/2}dx$, and

$u=x$ and $dv=(x+a)^{5/2}\,dx$.

Then,

$$\int x^3\sqrt{x+a}\,dx=(x+a)^{3/2}[2/3x^3-4/5x^2(x+a)+16/35x(x+a)^2-32/315(x+a)^3]+C$$

Direct solutions were also given by: Helen M. Scott, Baltimore, Md., and Hugo Brandt, Chicago by use of substitution $x=z^2-a$. Alan Wayne, Flushing, L. I., N. Y. used $x=a\tan^2 y$. Roy Wild, New Boston, Mo. used $x=y-a$. Francis L. Miksa, Aurora, Ill, used $x=ay^2-a$.

Other solutions were given by Leon Benson, Boonton, N. J.; Isadore Gosz, West De Pere, Wis.; Louise Tewes, Covington, Ky.; Charles P. Louthan, Columbus, Ohio; and the proposers.

1982. *Proposed by Milton Schiffenbauer, Camp Wolters, Texas.*

The sum of the squares of 13 consecutive integers cannot be a perfect square.

Solution by Alan Wayne, Flushing, L. I., N. Y.

Set $S^2=(k-6)^2+(k-5)^2+\cdots+k^2+\cdots+(k+6)^2$, for integer k, or $S^2=13(k^2+14)$. Hence S^2 must be of the form $S^2=13^2T^2$, where T is an integer. Thus $k^2=13T^2-14$. If T is even, so is k; we set $T=2m$, $k=2n$, for any integers m and n, and find that $n^2=13m^2-7/2$, which is impossible. If T is odd, so is k; we set $T=2m-1$, $k=2n-1$, and find that $n^2-n=13m^2-13m-\frac{1}{2}$, which is also impossible. Consequently there is no integer k which satisfies the relation $S^2=(k-6)^2+(k-5)^2+\cdots+(k+6)^2$.

Solutions were also offered by Roy Wild, New Boston, Mo.; V. C. Bailey, Delaware, Ohio; Mildred Hopkins, Kaukakee, Ill.; Morris I. Chernofsky, New York City; Hugo Brandt, Chicago; Francis L. Miksa, Aurora, Ill. D. F. Wallace, St. Paul, Minn.; Patrick Camel, St. Albans, Vt.; and the proposer.

1983. *Proposed by Howard D. Grossman, N. Y. City.*

Find the sum to infinity of the series

$$1/2+1/3-1/4-1/5+1/6+1/7.$$

Solution by Helen M. Scott, Baltimore, Md.

This may be written as the sum of two series:

$$1/3-1/5+1/7-1/9+\cdots+1/2(1-1/2+1/3-1/4+\cdots)$$

$$\tan^{-1}x=x-\frac{x^3}{3}+\frac{x^5}{5}-\frac{x^7}{7} \tag{1}$$

For $x=1$

$$\tan^{-1}x=\frac{\pi}{4}=1-\left(\frac{1}{3}-\frac{1}{5}+\frac{1}{7}\right) \tag{2}$$

$$\therefore 1-\frac{\pi}{4}=1/3-1/5+1/7- \tag{3}$$

$$\log(1+x)=x-\frac{x^2}{2}+\frac{x^3}{3}-\frac{x^4}{4} \tag{4}$$

For $x=1$

$$\log_e 2=1-1/2+1/3-1/4 \tag{5}$$

$\therefore$ the sum of $1/2+1/3-1/4-1/5+1/6+1/7$ is

$$1-\frac{\pi}{4}+\frac{1}{2}\log_e 2. \tag{6}$$

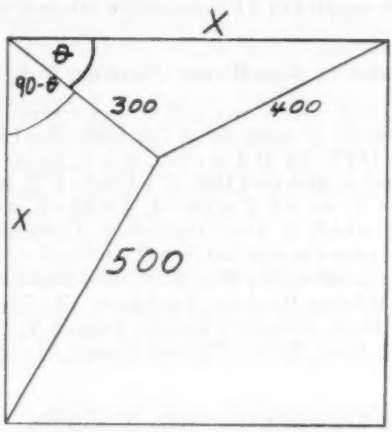
Solutions were also offered by Hugo Brandt, Chicago; Francis L. Miksa, Aurora, Ill.; Alan Wayne, Flushing, L. I., N. Y.; Mildred Hopkins, Kaukakee, Ill.

1894. *Proposed by E. N. Shuster, Trenton, N. J.*

From a point within a square three lines are drawn, one to a vertex. If the lengths of the lines are 300, 400 and 500, find the length of a side of the square.

Solution by V. C. Bailey, Delaware, Ohio

If we think of drawing the 300 and 400 lines to two of the vertices, respectively, then the 500-line may be drawn to either of the two remaining vertices. Therefore, there will be two solutions.



If the 500-line is drawn to the nearer vertex, we have the following solution:

Using the Law of Cosines we get

$$\cos\theta=\frac{x^2-70{,}000}{600x} \tag{1}$$

and

$$\cos(90-\theta)=\sin\theta=\frac{x^2-160{,}000}{600x} \tag{2}$$

$$\sin^2\theta+\cos^2\theta=1 \tag{3}$$

$$x^4-410{,}000x^2+15{,}250{,}000{,}000=0 \tag{4}$$

$$x=606.1 \quad \text{and} \quad 190.6. \tag{5}$$

With the 500-line drawn to the farther vertex, and reasoning similarly, we get the following equation and solutions:

$$x^4-340{,}000x^2+6{,}500{,}000{,}000=0 \tag{6}$$

$$x=565.4 \quad \text{and} \quad 142.6. \tag{7}$$

The side of the square may have either of the approximate values

606.1 or 565.4

The other vlues of x, namely,

190.6 and 142.

represent the sides of the squares when P is outside.

(NOTE: In working the problem, the distances 3, 4, and 5 should be used instead of 300, 400, and 500.)

Solutions were also offered by Hugo Brandt, Chicago; Helen M. Scott, Baltimore, Md.; Francis L. Miksa, Aurora, Ill.; Alan Wayne, Flushing, L. I.,N. Y.; Martin Cohen, Kew Gardens, N. Y.; L. R. Galebaugh, Palmyra, Pa.; Isadore Gosz, West DePere, Wis.

1985. *Proposed by Walter R. Warne, Columbia, Mo.*

Solve the system

$$\frac{x}{y^2-3}=\frac{y}{x^2-3}=\frac{-7}{x^3+y^3}$$

Solution by Roy Wild, New Boston, Mo.

When the first two fractions are simplified, one obtains

$$(x-y)(x^2+xy+y^2-3)=0. \tag{1}$$

The first and third fractions yield

$$x^4+xy^3=-7y^2+1. \tag{2}$$

This with $x=y$, gives

$$x=\pm\tfrac{1}{2}\sqrt{-7\pm\sqrt{217}} \text{ (Four solutions).}$$

From (1) $7x^2+7xy+7y^2-21=0$. This and (2) gives

$$x^4+xy^3-7x^2-7xy=x(x+y)(x^2-xy+y^2-7)=0 \tag{3}$$

$x=0$ and $x+y=0$ do not yield solutions of the given equations.

Solving

$$x^2+xy+y^2=3 \text{ and}$$
$$x^2-xy+y^2=7$$

one obtains solutions $(1, -2)$; $(-1, 2)$; $(2, -1)$; $(-2, 1)$.

Other solutions or part solutions were given by Alan Wayne, Flushing, L. I., N. Y.; V. C. Bailey, Delaware, Ohio; Emily C. Hansen, Minneapolis, Minn.; Martin Cohen, Kew Gardens, N. Y.; Isadore Gosz, W. DePere, Wis.; Hugo Brandt, Chicago; Helen M. Scott, Baltimore, Md.; Harry W. Ogden, Willard, N. Y.; Margaret Golway, Ovid, N. Y.; Christina Lund, Baileytown. N. Y.; Hazel S. Wilson, Annapolis, Md.; and the proposer.

1986. *Proposed by Agnes Dunlap, Providence, R. I.*

If the diagonals of a cyclic quadrilateral are perpendicular to each other, the line through their point of intersection perpendicular to one side bisects the other side.

Solution by Isadore Gosz, W. DePere, Wis.

Since $BD \perp AC$ and $GEF \perp CD$, CEF, ABE, and DEF are right triangles.

$$\angle 1=\angle 2, \quad \therefore \triangle DEF \sim ABE, \quad \therefore \angle 3=\angle 4$$
$$\angle 4=\angle 5, \quad \therefore \triangle CEF \sim \triangle ABE, \quad \therefore \angle 6=\angle 2$$

But

$$\angle 6=\angle 7 \text{ and } \angle 3=\angle 8.$$
$$\therefore \angle 2=\angle 7 \text{ and } \angle 4=\angle 8.$$

Triangles AGE and GBE are now proved isosceles. So

$$AG=GE \text{ and } BG=GE$$

$$\therefore AG = BG.$$

Solutions were also offered by Martin Cohen, Kew Gardens, N. Y.; V. C. Bailey, Delaware, Ohio; Francis L. Miksa, Aurora. Ill.; Hugo Brandt, Chicago; Abraham L. Epstein, Asbury Park, N. J.; Kate King, McDuffietown, N. Y.; W. R. Warne, Columbia ,Mo.; Mrs. W. R. Warne, Columbia, Mo.; Mabel Ogden, Hoyts Corners, N. Y.; Helen M. Scott, Baltimore, Md.; Alan Wayne, Flushing, L. I., N. Y.; Roy Wild, New Boston, Mo.; and the proposer.

HIGH SCHOOL HONOR ROLL

The Editor will be very happy to make special mention of high school classes, clubs, or individual students who offer solutions to problems submitted in this department. Teachers are urged to report to the Editor such solutions.

1896. *Ronald Weigand, Arlington Heights, Ill.*

PROBLEMS FOR SOLUTION

1999. *Proposed by Hugo Brandt, Chicago.*

If the sides of a triangle are s_1, s_2, s_3 and the medians m_1, m_2 and m_3,

a) Calculate the medians in terms of the sides
b) Calculate the sides in terms of the medians

2000. *Proposed by Mrs. Walter R. Warne, Columbia, Mo.*

Find the highest powers of 2 and 7, which are factors of 50!

2001. *Proposed by Ray Dubish, Missoula, Mont.*

Prove the rule for squaring a number ending in 5, which follows:

Multiply the number with the 5 omitted by one more than this "shortened" number. To this product annex the number 25. The result is the square of the number.

2002. *Proposed by William Cox, Willard, N. J.*

Show that the 12th power of an integer is of the form $13m$ or $13m+1$.

2003. *Proposed by Hugo Brandt, Chicago.*

Solve for x:

$$(x^2-2)f(m^3) = f(m^5)+x, \quad \text{if} \quad f(m) = m+\frac{1}{m}:$$

2004. *Proposed by Chas. P. Louthan, Columbus, Ohio.*

Find the general solution of

$$\left(4x^2+y^2\cos\frac{y}{x}\right)dx = xy\cos\frac{y}{x}\,dy.$$

BOOKS AND PAMPHLETS RECEIVED

MATTER AND LIGHT, THE NEW PHYSICS, by Louis de Broglie, *Membre de l'Institut Nobel Prize Award, 1927, Professeur à la Faculté des Sciences de Paris.* Translated by W. H. Johnston, B. A. Cloth. Pages 300. 12×19 cm.

1946. Dover Publications, 1780 Broadway, New York 19, N. Y. Price $2.75.

LECTURES ON THE CALCULUS OF VARIATIONS, by Gilbert A. Bliss, Ph.D., *The University of Chicago.* Cloth. Pages ix+296. 15×23 cm. 1946. University of Chicago Press, Chicago, Ill. Price $5.00.

THE AMAZING ELECTRON, by James I. Shannon, S. J., *Head of the Department of Physics, St. Louis University.* Cloth. Pages xii+248. 13.5 ×21.5 cm. 1946. The Bruce Publishing Company, 540 N. Milwaukee St., Milwaukee 1, Wis. Price $4.00.

MATHEMATICS AND LIFE, by F. B. Knight, J. W. Studebaker, and Gladys Tate. Book 1. Cloth. Pages 480. 13.5×20 cm. 1946. Price $1.04. Book 2. Cloth. Pages 512. 13.5×20 cm. 1946. Price $1.08. Scott, Foresman and Company, 623 S. Wabash Avenue, Chicago 5, Ill.

CURVES, by Lt. Col. Robert C. Yates, AUS., *United States Military Academy, West Point, New York.* Spiral binding. Pages iii+230+iv. 14×22.5 cm. 1946. United States Military Academy, West Point, New York.

ELECTRIC MOTOR REPAIR, by Robert Rosenberg, B.S., *Brooklyn High School of Specialty Trades, New York City.* Duo Spiral Binding. Pages 243+308. 14×23 cm. 1946 Murray Hill Books, Inc., 232 Madison Avenue, New York 16, N. Y.

FUNDAMENTALS OF AVIATION, by Norman Potter and William J. Konicek. Paper. Pages 107. 21×28 cm. 1946. Price $1.00. Educational discount to teachers, school groups and Air Scouts. Lind Aviation Devices, Inc., Binghamton, N. Y.

VOCATIONAL EDUCATION IN THE YEARS AHEAD, A Report of a Committee to Study Postwar Problems in Vocational Education. Bulletin No. 234. Pages xiv+329. 14×23 cm. Superintendent of Documents, Washington 25, D. C. Price 50 cents.

EDUCATORS GUIDE TO FREE FILMS, Sixth Annual Edition, compiled and edited by Mary Foley Horkheimer and John W. Diffor, M.A., Visual *Education Director, Randolph High School, Randolph, Wisconsin. Educational Consultant* John Guy Fowlkes, Ph.D. *Professor of Education and Dean of Summer Session, University of Wisconsin.* Pages 303. 21×27.5 cm. 1946. Educators Progress Service, Randolph, Wisconsin. Price $4.00.

ABSTRACT OF PAPERS, 110th Meeting, American Chemical Society. Chicago, Ill. Pages 507. 13×21 cm.

LESSONS IN SCIENCE SERIES, Number One, THE STORY OF THE THERMOMETER, by Benjamin De Leon, *Science Department, South Side High School, Newark, N. J.* Pages 32. 15×22.5 cm. 1946. Science Learning Aids Publishing Co., Box 8085, Clinton Hill Station, Newark 8, N.J. Price 35 cents, 51 copies or more 25 cents each.

VISITING TEACHER SERVICES, Report of a Conference Called by the Commissioner of Education and Held in the U. S. Office of Education, Washington, D. C., June 1945, Leaflet No. 75, by Katherine M. Cook, *Chief, School Organization and Supervision, Division of Elementary Education.* Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Price 5 cents.

BOOK REVIEWS

INTRODUCTION TO ATOMIC PHYSICS, by Henry Semat, Ph.D., *Associate Professor of Physics, The City College, College of the City of New York.* Revised and enlarged. Cloth. Pages xi+412, 15×23 cm. 1946. Rinehart and Company, Inc., New York. Price $4.50.

This textbook is intended for a one-semester course of three hours per week for science students who have had one year of general college physics and a course in the calculus. It is a revision and enlargement of the first edition, which appeared in 1939 and ran to 359 somewhat smaller pages.

The revision consists largely in an improvement in the division of the book into slightly shorter chapters, in minor rearrangements of material, in the redrawing of some of the diagrams and in the use of more recent numerical data. The enlargement is more noticeable. Frequently throughout the book a paragraph or two has been added for clarity or to bring the treatment up to date. New photographs have been included and sections have been interpolated to discuss such recent inventions or discoveries as the betatron and the production of nuclear photofission by x-rays from it.

Part I, on the foundations of atomic physics, begins with a review of elementary electricity and magnetism, including only such topics as will be needed later in the text. This is followed by chapters on charged particles, electromagnetic radiation and the wave-particle duality. Part II discusses the extranuclear structure of the atom, beginning with the Bohr theory of the hydrogen atom and including an elementary treatment of atomic spectra and electron configurations. The results of quantum mechanics are used freely where applicable, but without derivation.

As is to be expected, the chief additions are in Part III, on the nucleus of the atom. Most of the work that has been done in this field since 1939 has been, and unfortunately still is, shrouded in military secrecy. However, it has been possible to include a considerable amount of material on nuclear fission, which was mentioned in one paragraph in the first edition. Much of this material has been drawn from the Smyth Report, although some of it had been published before this country entered the war.

The typography is good and misprints seem to be at a minimum. Despite the increase in the number of pages, the book is much thinner and lighter than the first edition, owing to the use of wartime paper. This advantage is partially offset by a reduction in the clarity of the half-tones; the reader is not distracted by the fact that the type shows through the paper slightly.

Selected references for additional reading are given at the end of each of the nine chapters and all but the last of these are provided with sets of problems, to which answers are given. There are nine appendixes, giving some mathematical derivations and tables of atomic weights, masses of isotopes, and other physical constants. There is a full index.

As in the case of the first edition, the book is well and clearly written. Some infelicities of expression do not greatly detract from its readability. A student with the preparation assumed by the author should have no great difficulty in following the text. It is the reviewer's opinion, however, that the amount of material included is too extensive for a one-semester course. Many teachers would doubtless wish to make a number of omissions in details.

JOSEPH D. ELDER
Wabash College

PLASTICS: SCIENTIFIC AND TECHNOLOGICAL, by H. Ronald Fleck. M.SC., F.I.C. Cloth. Pages x+292+33, 14×22 cm. 1945. Chemical Publishing

Company, Inc., Brooklyn, N. Y. Price, $6.50.

This authoritative book by an English scientist brings together material dealing with all phases of the plastics industry, stressing not only the theoretical principles and the related chemistry, but the practical application of this knowledge.

Beginning with a brief history which shows the recent rapid strides in the field, the author summarizes the raw materials used and the elementary physical and chemical properties of each. A comprehensive chapter on the chemistry of plastics follows. Methods of manufacture are discussed with emphasis on the necessity of a knowledge of controls such as temperature and pressure.

The problem of rubber substitutes introduces the chapter on rubber-like plastics. The raw materials are reviewed and the characteristics of the finished products are considered. The author's view of the subject indicates that he believes that natural rubber will continue to have a place in industry and at the same time promote the economy of the world by aiding the countries producing it.

The great advantage of the thermo-plastics listed lies in the controls possible through the reapplication of heat and pressure in the moulding procedure. Optical clarity, particularly to ultraviolet light, leads to their uses for window-glass substitutes and for "piping" light.

The thermo-setting plastics are of great value due to their properties of high tensile strength and high dielectric constant. The theory explaining these characteristics is discussed in some detail. In observing the developments possible through the use of large sheets of these materials in prefabricated houses, the author pleads for homes which express the individualities of the occupants.

The replacement of natural resins by synthetic products makes possible a wide variety of paints and organic protectives. The cellulose lacquers and synthetic enamels receive attention. The chemistry of resins is given in some detail. Other topics are the glycerol substitutes and purification of water by means of synthetic resins. The author's hope for small units for "de-mineralizing" water had in mind the aid it would be to seamen and aviators awiting rescue at sea.

Approaching the subject of synthetic fibres and textiles, the type are first summarized and then discussed individually. Best known to most people are the cellulose fibre, Rayon, and the protein-like fibre, Nylon. The history, the techniques developed and the physical properties of the products are well presented.

The field of adhesives, both protein-based products and synthetic resins, is considered from the stand-point of manufacture and important uses are suggested. Plywood manufacture depends not only on the adhesive used but upon moisture content, temperature and pressure, all of which can be controlled. Methods of obtaining the veneers are illustrated.

An important aspect of any manufacturing process, the development of dies and moulds, is of extreme importance in this industry. The materials and types are discussed and illustrated. The manufacture of the plastic articles with the aid of hydraulic systems includes steps involving the preparation of powder, pre-heating, techniques of injection and extrusion, the inspection of finished products and the use of polarized light for inspection of strains in transparent materials. When essential, other types of testing, chemical, physical, and electrical, are called into use. The author includes a chart for a qualitative scheme of identification of commercial plastics by flame colors and by odors.

This book, which is of great value to the chemist and technician, has a message for the layman. The completeness of its exposition of the wide

variety of plastics and the place of each in our modern economy is commendable and makes the book valuable to the non-technical reader who could not work through the pages of fine-print and chemical formulae. The same position of the author in feeling that plastics will not solve all the problems of the world will have some influence in charting the future of an industfy which has and will add to the material blessings of life.

ROBERT L. PRICE,
Joliet Junior College

MAKING SURE OF ARITHMETIC—book 5, 7, & 8 by Robert Lee Morton, *College of Education, Ohio University;* Merle Gray, *Director of Elementary Educ., Hammond, Indiana;* Elizabeth Springstun, *Training Teacher, National College of Education, Evanston, Ill.;* William Schaaf, *Department of Education, Brooklyn College, Brooklyn, N. Y.* Cloth. Pages iii+348 each. 15.5 cm. ×21 cm. 1946 Silver Burdett Company, Chicago, Ill. Price $1.04 each.

As the title implies the emphasis in these texts in Arithmetic for grades 5, 7 & 8 is; making sure of arithmetic knowledge through complete understanding. The authors have done this by such things as: is the answer sensible; estimate the result before completing the problem; comparing solutions, one of which is incorrect. They have discussions on deciding what to do before starting to work problems; lists of problems without numbers; problems where items of information needed are not given and the pupil must decide what is needed. The thinking process on problems is discussed in step by step procedures for various types of problems. Emphasis is placed on needed vocabulary with pages entitled, "understanding terms," discussing and asking questions on the new terms. Through out, the books ask for checks in the work of the pupil.

Decimals are used in book 5 in connection with money, methods of counting out change and how much change should be received. They are formally presented in the last chapter. Special effort has been made to give a clear understanding of percent and percentage. Much space is given to common fractions and their understanding. Comparison is made of the size, the effect of changing numerator or denominator, decimals and the many uses of fractions. Cancellation is introduced only after understanding and under the title, "Short Cut." Short division is introduced in book 7 the same way. A good deal of work is done with units of measure and the things measured by them. The precision of measure is considered and very good pictures and examples are used to give better understanding of the approximateness of all measure. The place of zero in our mathematics is given more space than in most texts. Continuity is maintained by comparing new operations with those of the past and pointing the likenesses. The Jiffy Quiz, Keeping in Practice, and Making Sure, are used to improve the use of fundamental operations.

The authors use the social implications as illustrations and applications and therefore only book 8 has units on; Earning a living; Borrowing Money; Sharing Risks and Benefits. The other texts have units on; Form and Measurement; Percentage; Decimals, and introduce the social problems as applications. There is plenty of problem material, the fundamentals are stressed with only 10 pages on algebra in book 8. The pictures are well done and appropriate. The book is pleasing to the eye and written so it is easy to read and understand. The authors state in the preface: "Children can—and should—enjoy arithmetic." This book is definitely headed in this direction.

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ONE WORLD OR NONE. A Report to the Public on the Full Meaning of the Atomic Bomb, Edited by Dexter Masters, Editor of *Science Illustrated*, and Katharine Way of the Metallurgical Laboratory, *University of Chicago*. Paper. Pages x+79. 21×28 cm. 1946. McGraw-Hill Book Company, Inc., 330 42nd Street, New York 18, N. Y. Price $1.00.

This is a series of short articles by fifteen of the atomic bomb scientists and authorities of high military and political rank with a Foreword by Niels Bohr and an Introduction by Arthur H. Compton. It is an attempt to give to the ordinary citizen the full meaning of the atomic bomb and its use as an instrument of destruction. From Philip Morrison's hypothetical picture of the destruction of New York City to Walter Lippmann's "International Control of Atomic Energy" it is instructive, startling, appalling —a remarkable book which should be read by everyone and kept constantly before every member of the peace conference.

G. W. W.

BULLETS BY THE BILLION, by Wesley W. Stout, *former Editor of the "Saturday Evening Post."* Cloth. 77 pages 12.5×20 cm. 1946. Chrysler Corporation, Detroit, Michigan.

This is a wonderful little book which tells the story of one war plant and its products, and how they were made. It is superbly illustrated in color showing views from the plant on the banks of the Ohio to the sandy beaches of Pacific isles. It tells the story of the rapid change of a Plymouth and Dodge truck assembly plant into a war industry for the production and packing of ammunition and the reconditioning and rebuilding of tanks and trucks. It shows how an agricultural country for 50 miles around Evansville, Indiana, furnished many of the arsenal employees.

G. W. W.

GROWTH OF THE JUNIOR COLLEGE

The way the junior colleges—newest segment of American higher education—have rolled up their sleeves to offer a strong, 1946-model education to a huge portion of the unprecedented throng of veterans and high school graduates clamoring for college entrnace this fall, is making educational history, and at the same time is bringing fulfillment to the hopes for a college education of thousands of young people who would otherwise have been doomed to disappointment. Junior college after junior college has managed to enlarge both its facilities and its staff to accommodate enrollment increases of anywhere from 400% to 2000% per institution.

The 355,000 students who will enter junior college this fall are just short of half as many students as were enrolled in *all* of higher education in 1943–44 as enumerated in the recent Snyder report to President Truman. Approximately 153,000 veterans will be included in the 355,000. Apparently the 30-year-old junior college movement, a distinctly American development, is now assuming the significance in United States higher education that experts have long predicted for it.

Despite their tremendous enrollment this fall, junior colleges could admit a total of about 33,000 more students than they expect to register. This excess capacity, however, is not distributedly evenly over the junior colleges; 3 out of every 5 estimate that their September enrollment will fill every available seat, despite the large increases in capacity which so many of them have made. The excess capacity is therefore distributed among only 40% of the junior colleges.

It also is not distributed evenly geographically. The junior colleges along the entire Eastern Seaboard, especially, can accommodate very few additional students, with the possible exception of Connecticut. This gives pertinence to the fact that of the 45 new junior colleges to be in operation this fall, no less than 21 will be along the Eastern Seaboard. Thirteen of these are to be publicly controlled institutions; 8 of them, privately controlled. The opening of the 13 new public ones is an especially significant event for the East—since, with the exception of Georgia, where there are 11, the entire Atlantic Seaboard has had until now only 17 publicly controlled junior colleges—as against 242 for the rest of the country.

Notable among the states where a good proportion of the junior colleges can still admit a relatively large number of additional students this fall are Kansas, Washington, and Kentucky.

The tremendous proportions of the boom for junior colleges can be shown most vividly by citing the enrollment increases for a few sample institutions from among the many strikingly affected. Riverside (Calif.) Junior College, for instance, which had 183 students in the school year 1944–45, expects 1600 students this fall, a 774% increase. La Junta (Colo.) Junior College will have a 1567% increase over 1944–45; the Junior College of Commerce, at New Haven, Conn., a 857% increase; Duluth (Minn.) Junior College, 733%. North Dakota State School of Science will lead all the junior colleges, with an expected 2319% increase.

ENGINEERS DEVELOP METHOD OF EXTRACTING LEVULOSE FROM SUGAR

A method of extracting levulose—a sugar that is half again as sweet as ordinary sugar—has been developed by the University of Colorado Engineering Experiment Station.

The new production method was developed by Martin M. Reynolds, junior research engineer at the University, working with Dr. Carl W. Borgmann, director of the U. of C. Experiment Station. The project is sponsored by the Sugar Research Foundation.

Although scientists have known for years that ordinary sugar is 50 per cent levulose (also known as fructose or fruit sugar), there has never been a commercial method for producing this sugar. Many research workers in this country and abroad have worked on the project. Reynolds' method appears to be the answer to the problem.

Officials of the Great Western and American Crystal Sugar companies say that commercial production of levulose in their plants may enable them to increase the use of their plants beyond the usual three months "campaign" each fall when the sugar beets are harvested. They point out that it may well open new markets for Colorado beet sugar and greater employment in their plants.

Levulose is never expected to take the place of ordinary sugar, Dr. Hockett said, but rather it should find a good market as a specialty sugar, where its own properties are particularly desirable. "It dissolves more easily than any other sugar and for that reason alone is very attractive to manufacturers of ice cream, jellies, baked goods, and soft drinks." Dr. Hockett explained. Since it enhances the flavor of fresh fruits, many housewives may prefer it to regular sugar.

Medical men also are interested in the new development. At Montreal General Hospital and Michael Reese Hospital in Chicago, doctors are experimenting with levulose made at the University to learn its behavior in the human body. Already levulose has proved valuable in making certain tests of liver efficiency in diabetic cases.